

Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

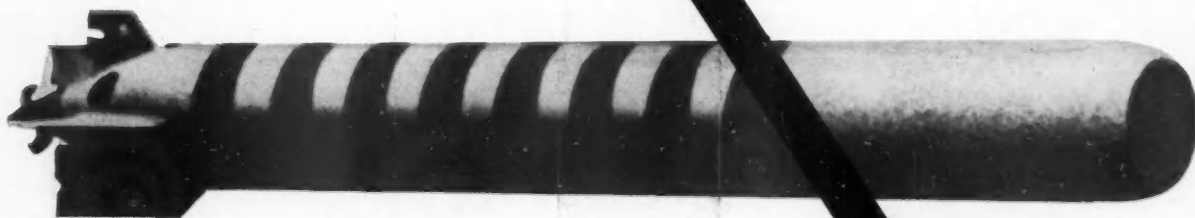
60 Cents

FEBRUARY 1959

The Pot & The Pendulum



Levels Road Graders



Stabilizes Torpedos

EXCLUSIVE!

Lunik's Guidance and Control System

Story starts on page 168

PARALLEL
UNAMBIGUOUS
STRAIGHT
BINARY OUTPUT



capacity:
10 DIGITS

resolution
per input
shaft revolution:
1024 COUNTS
(10 BINARY DIGITS)

accuracy:
1 COUNT IN TOTAL
CAPACITY



10 BIT ENCODER



7, 11, 13, 17 DIGIT
CAPACITY

resolution
per input
shaft revolution:
128 COUNTS
(7 BINARY DIGITS)

accuracy:
ONE COUNT IN
TOTAL CAPACITY
7 DIGITS—1 PART IN
128, 13 DIGITS—1
PART IN 8192, 17
DIGITS—1 PART IN
131,072, 19 DIGITS—
1 PART IN 524,288



BINARY



capacity:
0-2000, 0-3600,
0-20,000, 0-36,000,
0-360,000 COUNTS

resolution
per input
shaft revolution:
200 COUNTS

accuracy:
1 COUNT IN TOTAL
CAPACITY



BINARY
CODED DECIMAL



MODEL: 75B
SINE AND COSINE
GENERATED
SIMULTANEOUSLY
IN STRAIGHT BINARY

resolution
per input
shaft revolution:
1 AND 10 BITS PER
FUNCTION (7 AND 8
BITS PER QUADRANT)
WITH THE LIMIT 1;
ALSO QUADRANT
AND POLARITY
INFORMATION
PRESENTED FOR
EACH FUNCTION

Shaft and Servo
driven hermetically
sealed units
available.

accuracy:
1 COUNT IN TOTAL
CAPACITY



SINE COSINE

LIBRASCOPE



VERSATILITY IN DESIGN
FLEXIBILITY IN APPLICATION

packaged shaft-to-digital encoders

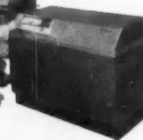
The Librascope Shaft Position-to-Digital Encoders are the most convenient and accurate devices for the conversion of analog shaft position into digital form. Added to the series of Librascope encoders, which include the Binary and Binary Coded Decimal, are the new 10-bit, 1024 count and Sine Cosine units. The 10-bit encoder provides parallel, unambiguous, straight binary representation of shaft position, and the Sine Cosine encoder is used where the natural functions of the sine and cosine are required with precision.

Features of Librascope encoders are: long life, high accuracy, double brush pickoff systems, serial and parallel readout into single or multiple scan matrices, solid state or vacuum tube, synchro-mounted, and time sharing (through the use of isolation diodes).

Associated circuitry can be designed to fit your data handling problem.

Write for Bulletins L10-1 and D-E10A for complete information.

Librascope's use of the
LGP-30 computer sim-
plifies complex design and
production problems,
and assures computer-
engineered quality in
meeting design and
delivery schedules.



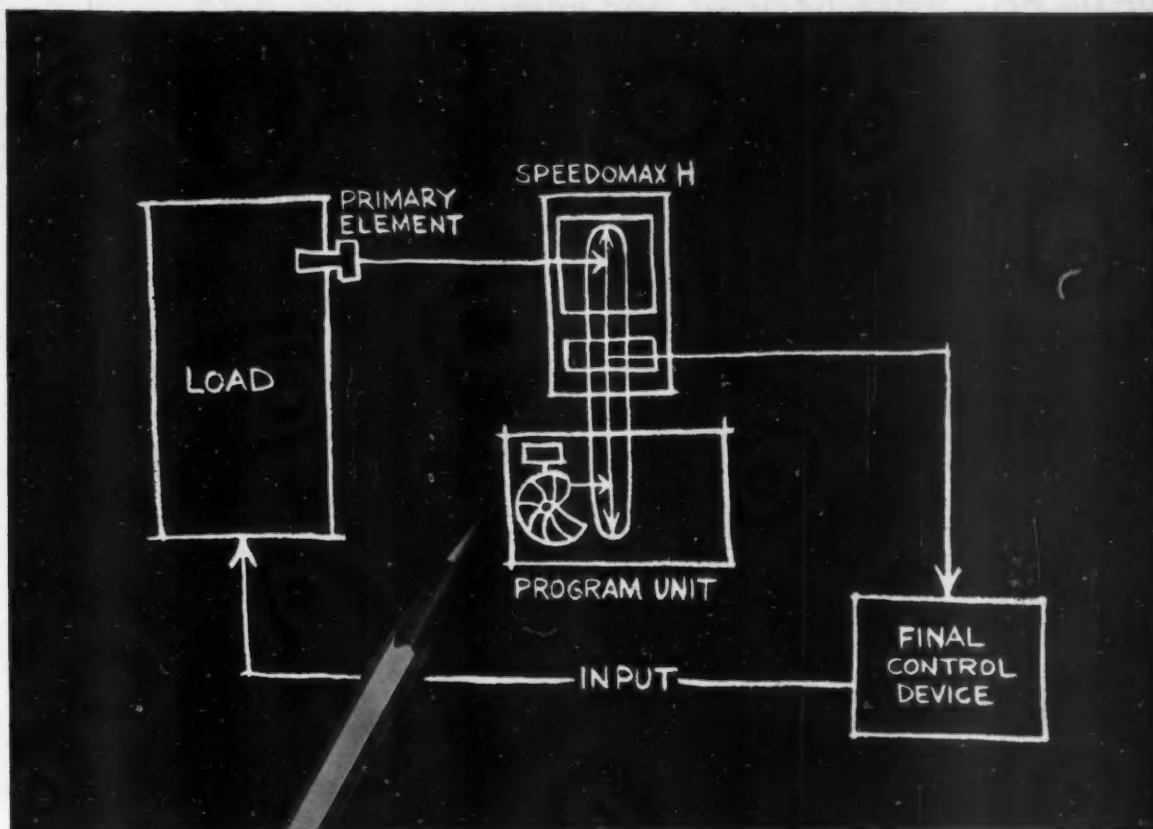
LIBRASCOPE



A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

LIBRASCOPE INCORPORATED • 808 WESTERN AVENUE • GLENDALE, CALIFORNIA

CIRCLE 1 ON READER-SERVICE CARD



Reproduce your time-temperature cycles exactly with L&N cam-type program control

At the flip of a switch you can heat . . . soak . . . and cool at a preset rate for a preset time with L&N's improved cam type program control! Whether your program is linear or non-linear, this control will continuously regulate input to reproduce *your* cycle . . . again and again.

Heart of the system is the program unit. Essentially it's a motor-operated cam and a control slidewire. The cam is calibrated . . . making it extremely easy to lay out and cut to any time-temperature cycle. Changing a cam to meet a new program takes only a minute. For additional flexibility, the unit has seven standard speeds . . . permitting a multiple number of programs.

Other elements in the control system include a primary element, a Speedomax® recorder and associated control relay, and a final control device.

Any change detected by the primary element and measured by the recorder is checked by the program unit, which regulates the final control device to keep the process on cycle.

Also available is a motor-operated front setter type of program control. Recommended for linear programs only, this system offers great flexibility within the range selected.

Both types are available for Two-Position or proportioning control . . . will regulate input to electric or fuel-fired furnaces.

Can your process benefit from programmed heating and cooling? If so, it'll pay you to investigate L&N program control. For more information, call your nearest L&N office, or write 4918 Stenton Ave., Philadelphia 44, Pa. Ask for Data Sheet ND46-33(4).




YOUR COMPUTER DESIGNS ARE BETTER
YOUR COMPUTERS PERFORM BETTER
when you draw from this comprehensive
range of

RAYTHEON RELIABLE COMPUTER TRANSISTORS

Raytheon PNP Germanium Fusion-Alloy Computer Transistors are approved for military applications. They provide:

- H_{FE} control at high currents
- High voltage ratings
- Fast switching speed
- Low saturation resistance
- Temperature range -65°C to $+85^{\circ}\text{C}$


ONE AMPERE, HIGH FREQUENCY, HIGH GAIN SWITCH



JEDEC-30 Type	Punch through Voltage min.	f_{cb} ave. Mc	H_{FE1} ave. $I_B = 1 \text{ mA}$ $V_{CE} = -0.25 \text{ V}$	H_{FE2} ave. $I_B = 10 \text{ mA}$ $V_{CE} = -0.35 \text{ V}$	I_{CO} at -12 V $I_C = -1 \text{ mA}$ $V_{CB} = -6 \text{ V}$ μA	r_b' ohms	C_{ob} μf
2N658	-24	5	50	40	2.5	60	12
2N659	-20	10	70	55	2.5	65	12
2N660	-16	15	90	65	2.5	70	12
2N661	-12	20	120	75	2.5	75	12
2N662	-16	8	30 min	50	2.5	65	12

designed for computer service

MEDIUM CURRENT, HIGH FREQUENCY, HIGH GAIN SWITCH


	JEDEC-30 Type	V_{CE} max. volts	f_{ab} ave. Mc	H_{FE1} ave. $I_B = 10 \text{ ma}$ $V_{CE} = -0.25 \text{ V}$	H_{FE2} ave. $I_B = 10 \text{ ma}$ $V_{CE} = -0.35 \text{ V}$	Rise Time* max. μsec
	2N404	-24	12	30 min.	—	—
	2N425	-20	4	30	18	1.0
	2N426	-18	6	40	24	0.55
	2N427	-15	11	55	30	0.44
	2N428	-12	17	80	40	0.33

made for computer service

tested for computer service

proved dependable in computer service

* $I_C = 50 \text{ ma}$, $I_{B1} = 5 \text{ ma}$, $R_L = 200 \Omega$, $I_{B2} = 5 \text{ ma}$; Grounded Emitter Circuit

	SUBMIN Type	V_{CE} max. volts	f_{ab} ave. Mc	H_{FE_1} ave. $I_B = 1 \text{ ma}$ $V_{CE} = -0.25 \text{ V}$	H_{FE_2} ave. $I_B = 10 \text{ ma}$ $V_{CE} = -0.35 \text{ V}$	Rise Time* max. μsec
	CK25	-20	4	30	18	1.0
	CK26	-18	6	40	24	0.55
	CK27	-15	11	55	30	0.44
	CK28	-12	17	80	40	0.33

PREFERRED by computer designers

Ratings at 25°C unless otherwise indicated
Dissipation Coefficients For 1 Amp types, in air $0.35^{\circ}\text{C}/\text{mW}$, infinite sink $0.18^{\circ}\text{C}/\text{mW}$
For med. current types, in air $0.40^{\circ}\text{C}/\text{mW}$, infinite sink $0.18^{\circ}\text{C}/\text{mW}$
For submin types, in air $0.75^{\circ}\text{C}/\text{mW}$, infinite sink $0.35^{\circ}\text{C}/\text{mW}$

Illustrations actual size



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Control ENGINEERING

FEBRUARY 1959

VOL. 6 NO. 2

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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Control ENGINEERING

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AMF Model AD-500 Centrifuge

How AMF uses CMC electronic counting equipment

For Motor Speed Control



Control panel close-up showing CMC Model 620 Go-No-Go Gauge

American Machine & Foundry's Model AD-500 is a high speed centrifuge for environmental testing of electronic components. Capable of exerting acceleration forces up to 50,000 G's at 22,000 RPM, the completely automatic Model AD-500 requires a precise speed control system. The system must provide maximum user flexibility and simplicity of operation. AMF chose the CMC Model 620 Go-No-Go Gauge to give their Model AD-500 precise speed control within any pre-selected limits.

Basically, the CMC 620 is a dual preset counter with a built-in time base, which provides output information in the form of relay closures for control purposes. Before the Model AD-500 is started, upper and lower RPM limits are set on the control knobs of the dual preset decade units. The test is then begun. As the centrifuge rotates, a tachometer generator provides the input information to the Model 620 which reads directly in RPM. If the motor speed falls within the pre-selected limits, the green "IN LIMITS" lamp lights. Above or below limits, the red "HIGH" or "LOW" lamp lights and the associated relay closure takes place, de-energizing or re-energizing the motor to hold the centrifuge within pre-selected limits.

OTHER APPLICATIONS...

Include—material flow control, production line testing of electronic instruments and components, pressure or liquid flow regulating-indicating systems, etc.



For complete specifications, description, price and applications information on the CMC Model 620, please address Dept. 082.

Computer-Measurements Corporation

5528 Vineland Ave. • No. Hollywood, Calif.
Phone STanley 7-0401 • TWX: NHOL 2160

MEASURING UNIT

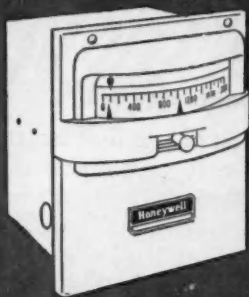
- A. A thermocouple signal to a d'Arsonval galvanometer, the only moving part, moves the indicating pointer up scale.
- B. Aluminum vane adjusts the amount of light received by the photocell from the operating lamp.
- C. If operating lamp or photocell fails, output voltage assumes a value equal to high temperature.



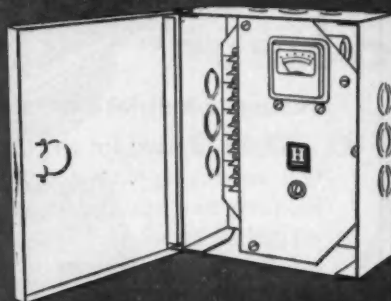
CONTROL UNIT

- D. A one-stage magnetic amplifier amplifies small current from the photocell in the measuring unit. This is the only active electronic element in the controller.
- E. Pilot light goes out on line power failure.

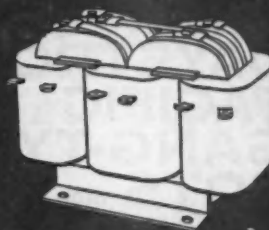
Pyr-O-Volt controller is dependable and trouble-free. Built-in voltage regulator maintains voltage within $\pm 1\%$ of level required for maximum operating stability. Thermocouple burnout protection is optional. Spare operating lamp is supplied with all instruments. Available in both horizontal and vertical case models.



MILLIVOLTMETER CONTROLLER



MAGNETIC AMPLIFIER



SATURABLE REACTOR

For your electric heating applications...

Use this accurate, dependable *Pyr-O-Volt** controller

- No tubes to wear out
- Voltage regulation
- Fail-safe design
- Contactless, stepless control

Here's an accurate instrument for reliable stepless control of saturable reactors, r.f. generators and other power amplifiers. It has a proportional band adjustable from $\frac{2}{3}\%$ to 5%, and a manual reset adjustment which shifts the control point over 100% of the proportional band.

The *Pyr-O-Volt* controller can control saturable core reactors up to 100 kva, if used with a Brown magnetic amplifier. You can also use this proportional output millivoltmeter-controller with the General Electric *Reactrol***, and with the Westinghouse *Furnatron****. Complete packaged systems available.

Contact your nearby Honeywell field engineer for complete details. He's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

● REFERENCE DATA: Specification S103-5

*Tradename, Minneapolis-Honeywell Regulator Co.

**Tradename, General Electric Co.

***Tradename, Westinghouse Electric Corp.



First in Control

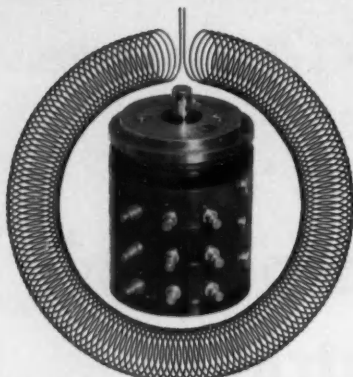
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FEBRUARY 1959

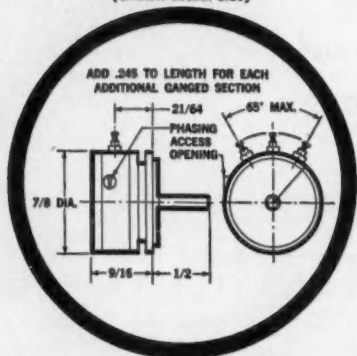
7

*solve your phasing
problems with*

DAYSTROM PACIFIC GANG-TYPE POTS 100 Ω to 50K



Model 319 Miniature Wire-Wound Potentiometer
(shown actual size)



ADJUST TO EXACT REQUIREMENTS. Each wiper can be positioned *independently* to solve complex phasing, reliability, resolution and linearity problems.

NEED LITTLE SPACE. Sections only $\frac{7}{8}$ " in diameter. Each section adds less than $\frac{1}{4}$ " to overall case length.

EXCEPTIONAL STABILITY. No clamping rings needed to gang sections. Pots remain stable despite the rigors of temperature, altitude, and vibration encountered by aircraft and missiles.

For complete specifications, contact the representative in your area...or write the factory direct.

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CONTROL ENGINEERING

SHOPTALK

Putting industrial control components to work

Sensing a need for the dissemination of practical information on the application of control system components in industry, next spring CONTROL ENGINEERING will cosponsor, with the School of Electrical Engineering and the Div. of Adult Education of Purdue University, a Conference on Industrial Control System Components. To be held May 4 and 5 at Purdue's Memorial Center in Lafayette, Ind., the conference will concentrate on exploiting the characteristics of the newest control components in industrial systems. See page 35 for the details, and get your reservations in early.

The printer goofed

Imagine our embarrassment when we discovered that the printer didn't perforate the January feature form, particularly after we'd advertised it in last month's *Shoptalk* and asked for your comments. The articles are perforated this month, and will be in all succeeding issues (we hope).

Karp invades Texas

Just about the time this issue is mailed, Associate Editor Harry Karp will be sharing the gospel with fellow control engineers at two technical society meetings: the Houston ISA section on Jan. 26 and the Sabine-Neches ISA section on Jan. 27. On these stopovers, items on a two-week editorial survey of the Gulf Coast, Harry will discuss sampled-data control, computing control, self-adaptive control, and non-interacting-variables control, and then describe progress made by various engineering groups in converting these advanced control principles to working control equipment.

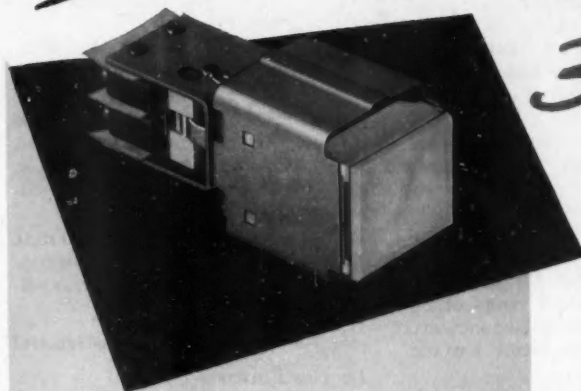
Experience plus education pays off

Howard S. Andrews, author of the survey of automatic tank-level gage on page 92, achieved his present position at the Bayway (N. J.) Refinery of Esso Standard Oil Co. the hard way, working days and going to college nights. Starting as a technician in the Refinery Laboratories in 1937, Howard advanced through the ranks, from technical assistant in the Instrument Section of the Gas Laboratory, and technical assistant to the head of the Instrument Dept., to field engineer in the Mechanical Dept., the position he now holds. During the same period (minus five years as an Army and Air Force officer) he acquired a BS in ChE from Newark College of Engineering. During his two tenures as technical assistant he gained considerable knowledge of plant instrumentation problems and was responsible for adopting laboratory analyzers for plant operation.



New **ELECTRO SNAP**

"PUSH-ON, PUSH-OFF" ALTERNATE ACTION LIGHTED PANEL SWITCH



3 units in 1 compact mounting;

use singly or in "stacked" arrangement

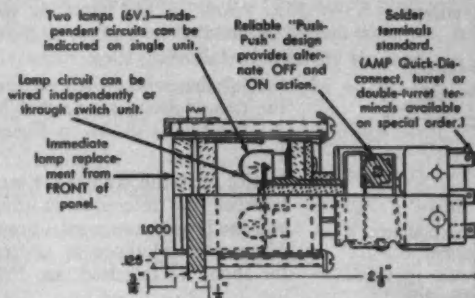
The compact, modular design of this new Electro-Snap "Push-Push" alternate-action, panel-mounted switch combines a two-piece, color-coded button, pilot light and switching unit in one space-saving component. Two or more units may be "stacked" side-by-side in one panel slot. This eliminates congestion while achieving greater operating efficiency and quality appearance than where separate button, light and switch units are used.

Wide range of configurations permits almost unlimited application for control and indicating operations.

Almost unlimited operating and indicating conditions can be provided for sequencing, movement-limit, start-and-stop and similar applications on missile, electronic and industrial controls through variation of:

- circuit arrangements of switch and pilot lights
- colored lights for color monitoring
- colored push-buttons for color coding

For full application details and specifications contact your local representative or write for data on Standard (C6 Series) Electro-Snap "Push-Push" Panel Switches.



STANDARD MODELS (C6-Series)

Lighted Push-Button Panel Switches

Standard models furnished with two-piece colored button, two 6V. lamps, two basic switches (E4-103) with solder terminals.

C6-S3—(shown above)—"Push-Push", alternate action.

C6-S2—Momentary action with over-centering device, positive feel.

C6-S1—Momentary action.

Model C6-S0 — for pilot light duty only. Consists of 2-piece colored button and lamp unit with two 6V. lamps. (No switching mechanism).

- 2-piece color-coded button; 5 colors available.
- Barriers ordered separately — to meet panel requirements.
- 28V. lamps available on special order.

BASIC SWITCH OPERATING CHARACTERISTICS

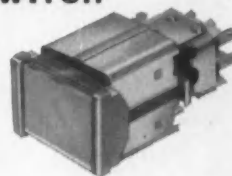
Contact ArrangementD.P.D.T.
Travel3/32 Approx.
Contact Pressure60 Grams
Contact Gap020 Max.
Temp. Range-65° F to +180° F.
Current Rating5A @ 125/250 V.A.C.
	4A Res @ 30 V.D.C. 2.5A Ind @ 30 V.D.C.

MOMENTARY-CONTACT

PUSH-BUTTON PANEL SWITCH

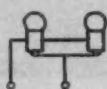
This momentary-contact, lighted push-button panel switch (C6 Series) has the same space-and-cost-saving features as the "Push-on Push-off" switch above. It is available in various configurations to permit application to a wide range of indicating and switching operations.

For details, write for "Bulletin C8"



- Complete push-button switch unit or pilot-light assembly can be supplied in any of the three following circuit arrangements. (solder terminals on lamp assembly).

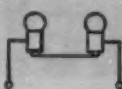
Parallel



2-Circuit Common Ground



Series



- The double-pole, double-throw switching unit may be wired normally-open or normally-closed.



ELECTROSNAP CORPORATION

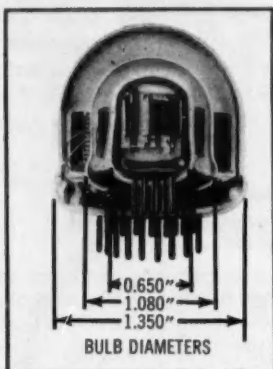
4248 West Lake Street, Chicago 24, Illinois
Telephone VA 6-3100 TWX No. CG-1400

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FEBRUARY 1959

Burroughs
NUMERICAL
READOUT TUBE
NIXIE®

**lowest power
any
electronic
readout**



**ALL ELECTRONIC IN LINE READOUT
CONTAINING TEN DIGITS "0" THRU "9"**

MINIATURE	STANDARD	SUPER
0.2 watts	0.4 watts	0.5 watts

**NIXIE TUBE EXCLUSIVE
FEATURES:**

- ALL ELECTRONIC
- LOWEST COST
- LIGHTEST WEIGHT
- MOST READABLE FOR NUMBER SIZE
- SMALLEST VOLUME ANY NUMBER SIZE
- MAXIMUM TEMPERATURE, SHOCK AND VIBRATION SPECS



CIRCLE 10 ON READER-SERVICE CARD
10 CONTROL ENGINEERING

FEEDBACK

But, but . . .

TO THE EDITOR—

Mr. Barron's article on phase measurement of distorted signals, in the November '58 *CONTROL ENGINEERING*, is of great interest to those engaged in the practice of control engineering, as related to ac servos and two-phase servomotors. The reference voltage phase-shifting circuit is particularly useful.

However, in the interest of accuracy I wish to question the use of a switching demodulator as a phase detector. While this is valid for sinusoidal waves, it can introduce errors of up to 90 deg for nonsinusoidal functions. The example given in Figure 1 would

while the in-phase fundamental frequency component of $f(t)$ is proportional to

$$\int_0^{2\pi/\omega} f(t) \sin(\omega t + \phi) dt$$

A rotating field device such as the two-phase servomotor itself has an output of this desired characteristic. With such a device as a demodulator, the utility of Mr. Barron's instrument would be increased.

E. G. Trunk
Servo Corp. of America
Hyde Park, N. Y.

. . . and rebuttal

TO THE EDITOR—

The particular wave form shown by Mr. Trunk in his letter to you would be handled by a phase analyzer operator by following these steps:

1. Set up the scale switch so that the demodulator is saturated by 2:1 exactly, as shown in Figure 1.
2. Notice that the coincident area between the reference sinusoid and the input wave is maximized where the reference is shifted for about 42 deg lead, see Figure 2.
3. Leave the phase dial at that point and then switch the scale switch to a higher range so that the signal is below demodulator saturation. Then read the average voltage, calibrated in rms.

The exact phase angle of a non-sinusoidal signal with respect to a reference frequency is a matter of definition. Mr. Trunk mentioned one definition of phase (that of the fundamental to reference) out of a number of possibilities. The phase analyzer is constructed to define phase as that angle at which the maximum signal area coincides with reference frames.

Other instruments compare the cross-over point of the unknown signal area with the reference cross-over. Such an

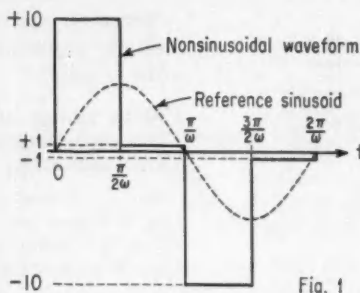


Fig. 1

be shown as having a 0-deg phase shift with a switching demodulator, whereas it actually has a 42.1-deg lead with respect to the reference sine wave. This is because the output of a switching demodulator is proportional to

$$\int_0^{2\pi/\omega} f(t) \frac{\sin(\omega t + \phi)}{|\sin(\omega t + \phi)|} dt$$

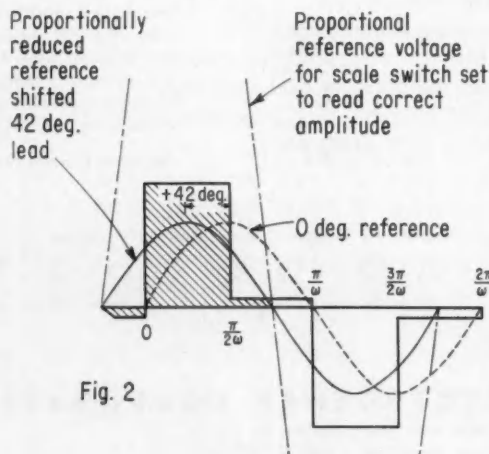


Fig. 2

use beam switching tubes for DISTRIBUTING
 use beam switching tubes for .. SWITCHING
 use beam switching tubes for ...SAMPLING
 use beam switching tubes forCODING
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 use beam switching tubes for **counting**

Beam Switching Tubes are 10-position high vacuum electronic tubes. Each tube may replace twenty or more transistors, tubes, or other components since a single cathode controls an electron beam to any one of the ten constant current output positions each with "Automatic" memory and high impedance switching.

BEAM SWITCHING TUBES CAN:

- switch sequentially or at random.
- be reset from any position in less than 1 μ sec.
- be preset to any position.
- be interconnected as a distributor of ANY number of positions.
- be operated as a word generator.
- be used as a wide band noise generator to 1000 Mcs.
- operate as a static device or at speeds over 20 Mcs.
- operate compatibly with tubes, transistors, cores and relays.
- directly operate BOTH local and remote Nixie® tube readout.
- directly supply outputs of several hundred volts.
- meet severe shock, vibration and temperature requirements.
- meet long life requirements (potential of 10,000-50,000 hours).
- convert binary to decimal and binary to analogue.

Catalog No. 1158 covering tube types and available literature will be sent by return mail on request.

In contrast to other types of components, Beam Switching Tubes will directly operate both Master and Remote Nixie indicator tubes at a lower cost and higher reliability. Even "all" transistor systems are using Beam Switching Tubes to perform digital functions.



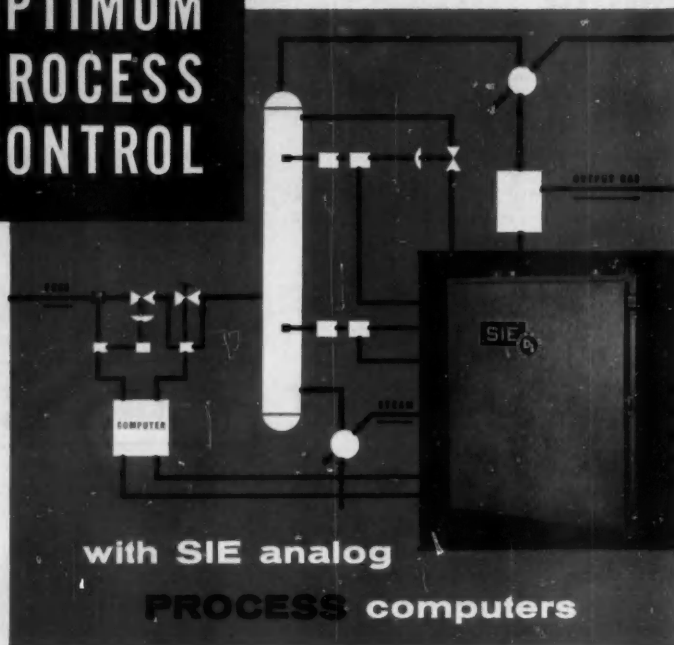
ANOTHER ELECTRONIC CONTRIBUTION BY
Burroughs Corporation

ELECTRONIC TUBE DIVISION

Plainfield, New Jersey

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OPTIMUM PROCESS CONTROL



with SIE analog
PROCESS computers

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RESEARCH AND DEVELOPMENT



CIRCLE 12 ON READER-SERVICE CARD
CONTROL ENGINEERING

FEEDBACK

instrument would indicate the illustrated signal to be 0-deg phase with respect to reference.

The phase analyzer voltage indication corresponds very closely to the torque-producing component of a non-sinusoidal voltage that is applied to the control winding of a two-phase servomotor.

As in all instruments, the phase analyzer has limitations that must be overcome by technique.

The particular wave form shown by Mr. Trunk affects the analyzer by:

1. Reduced sensitivity for sharper pulses.
2. Some loss of accuracy, since part of the unknown wave is not included in the averaging process.

Benjamin Barron
Magnetic Amplifiers, Inc.
New York, N. Y.

Wanted—supplier

TO THE EDITOR—

The article by E. J. Kompass in the September '58 issue describes a card-programmed diode function generator. I would appreciate it very much if you would send me the name and address of the company that manufacture this device.

James A. Mallin
Applied Physics Lab.
Johns Hopkins University
Silver Spring, Md.

Gladly. Electrol, Inc., 9000 West Pico St., Los Angeles, Calif. Ed.

Ball screw works better than rack

TO THE EDITOR—

The first sentence of the section entitled "All-electric valve actuators" on page 95 of the November, '58 issue of C&E does an injustice to our valve actuator. We went to some trouble to avoid a rack and pinion drive and, instead, employ a ball-bearing screw conversion from rotary to linear output motion. This is an important performance feature, since it is not only a more efficient and better balanced device from the force standpoint, but it also removes the disadvantage of a very low speed gear mesh. This disadvantage arises from the fact that if the valve remains in a single average position, although vibrating back and forth in the course of control action, a low-speed gear mesh would be riding on a single tooth and this tooth will be subjected to concentrated wear. A ball screw, on the other hand, provides not only translation output for rotation input, but it also provides a gear reduction

AC — dc

... or the **BEST** of everything
in process control

Swartwout pioneered electronic process control. It was evident that fully electronic control . . . with no signal lags, no dead bands, with infinite resolution in place of step changes . . . would offer the ultimate in process operation.

Swartwout's position was unique. As the first company, it had a clear field. The original research and development was free to select, test and determine the ideal circuit from countless combinations which were explored. Both AC and DC systems were built and tested.

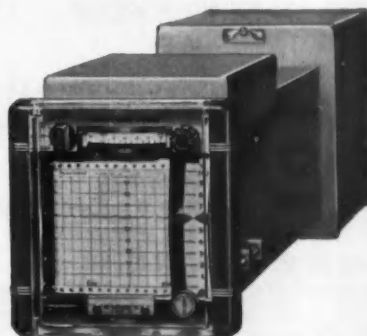
One combination emerged which incorporated the best characteristics for the control job: AC for the transmitter or sensor circuit because of its greater stability under high gains, the dependability of components, the trouble-free characteristics of the transmitter and the ease of explosion-proofing; then DC from the controller to the final element actuator.

The series of patents issued to Swartwout are evidence of the originality of concept and of real contributions to the art.

Pioneering has its difficulties, but it has one overwhelming advantage over the late comers; it is unrestricted, it offers free choice . . . nothing desirable is locked out.

And this "best of everything" in concept is offered to you in the most practical design of the instrument itself.

You are years ahead with Autronic Control . . . and you'll stay ahead with Swartwout leadership.



... world leader in
electronic process
instrumentation

THE SWARTWOUT COMPANY
18511 EUCLID AVENUE,
CLEVELAND 12, OHIO



MODEL D-1309 INDUCTION GENERATOR

FOR MISSILE POWER



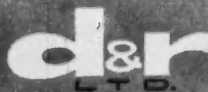
- ▶ **LOW ROTOR INERTIA**
LESS THAN 0.022 OZ. IN².
- ▶ **LOW STARTING TORQUE**
LESS THAN 1.5 OZ. IN.
- ▶ **HIGH POWER TO WEIGHT RATIO**
UP TO ONE HORSEPOWER PER POUND
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NO DEMAGNETIZATION DUE TO CIRCUIT OVERLOAD
- ▶ **MASS PRODUCIBLE**
RANDOM INTERCHANGEABILITY OF PARTS
- ▶ **IMPROVED RELIABILITY**
LARGE AIRGAP, CONSERVATIVE BEARING LOADS

The Model D-1309 is compact (1.5" O.D. x 1.67"), light weight (8.5 OZ.) and exhibits desirable performance characteristics. Its ratings at a shaft speed of 60,000 R.P.M. are:

Output frequency: 6,000 cps.

Power output: 100 Watts, single phase.

Other rotating power and control devices are available. WRITE FOR COMPLETE DATA.



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P.O. BOX 1500, SANTA BARBARA, CALIFORNIA
TELEPHONE: WOODLAND 3116

CIRCLE 14 ON READER-SERVICE CARD

CONTROL ENGINEERING

FEEDBACK

so that there is no single point subject to intense wear in the service described; instead, many teeth are exercised at the high-speed mesh. Thus, the force in the ball screw is carried by a large number of individual load points determined by the number of ball bearings.

J. A. Baring
Detroit Controls Div.
Norwood, Mass.

In the category of "if only"

TO THE EDITOR—

As you so effectively point out, the control field has almost unlimited potential for useful development. Unfortunately many areas of its greatest potential and usefulness seem to be almost completely ignored, perhaps because our ingenious scientist-engineers are engrossed with problems requiring a far higher degree of skill for their solution.

One of the great problems, capable of "control" solution, and the one of my interest, is that plague of the American city called "The Traffic Problem". More facets are involved in this problem than can possibly be discussed here. Among others, the problem includes room to park, room to drive our increasing number of private cars, and the decreasing use of public mass transportation facilities.

A great part of the problem of moving our people about a city could be solved by increased use of mass transportation; however, one can scarcely criticize the transit customer for refusing to patronize transportation media scarcely changed, except by the addition of electric or gasoline motive power, since horse-car days.

It is likely that the development of a transportation system which would compare with the private auto in speed and convenience for all uses would greatly reduce the use of the private automobile, restoring much of its lost convenience to those who continued its use, as well as conveniencing those who used the mass transportation facility.

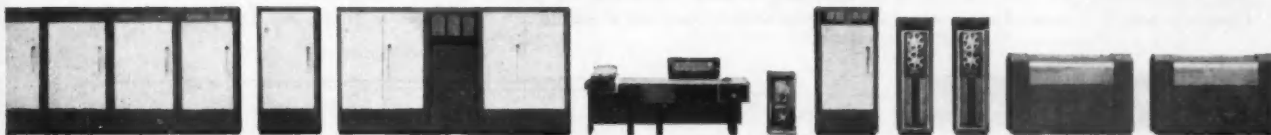
From my own studies, as well as from the work done on related subjects such as the much more complicated automatic warehousing systems and private auto steering and distance separation systems, I am certain that a system can be developed.

Donn H. Harper
Memphis, Tenn.

Well, you "creative new breed", here's your chance to brainstorm. Let's hear from you. Ed.



does both jobs equally well - Burroughs 205 Computer



From the sequential solution of long scientific problems to the mass processing of business data, the versatile Burroughs 205 electronic data processing system is ideally suited to a wide range of applications. Top capacity and speed in the medium price class, complete choice of input-output media, vast external magnetic tape storage. At work in many varied industries, the 205 has proven its superior dollar-for-dollar value. Its flexibility lets you grow into a larger Burroughs system as your needs increase. Burroughs extensive support program provides on-the-spot technical assistance for an advanced and complete line of data processing systems...all currently in production. Write for 205 brochure. ElectroData Division, Pasadena, California.



Burroughs Corporation

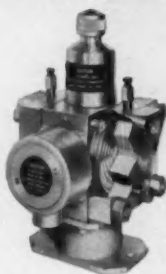
"NEW DIMENSIONS/in electronics and data processing systems"

CIRCLE 15 ON READER-SERVICE CARD

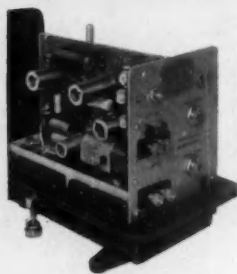
Taylor Instrument Companies ELECTRONIC

with all the outstanding features of

INSTANTANEOUS SENSING AND TRANSMITTING UNITS

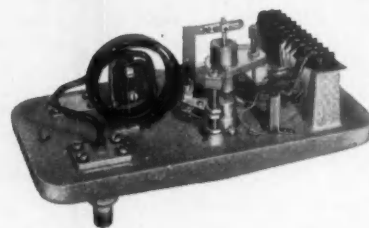


707Y DP Transmitter. It provides direct conversion from differential pressure to an AC signal. No maintenance . . . insensitive to vibration . . . self-draining and venting . . . positive over-range protection to 1500 psi . . . no process fluid in contact with internal parts, double stainless diaphragm seal between process and electrical components . . . no stuffing box, no bending members, no pivots, no flexible diaphragms nor torque tube seals. No vacuum tubes, no transistors—only a simple differential transformer. Highly linear adjustable silicone damping. Perfect for all flow applications. External zero, with wide range of zero suppression. Designed for use in Class I, Group D, Division I areas.



700T Potentiometer Transmitter. Unsurpassed for sensing and transmitting Temperatures (either thermocouple or resistance elements), Load, Speed, pH, or other millivolt signals. Electronic balancing eliminates the need for slide wires, batteries, standard cells or moving parts. Continuous vernier adjustment of span or zero is simplest on the market.

Interchangeable plug-in service "cans" permit quick adaptation of one instrument for use with different primary elements. Amplifier plugs in for simple servicing. Infinite sensitivity to the input signal. Weatherproof case permits field mounting. Users consider it the finest potentiometer transmitter available.



705T Pressure Transmitter. Bourdon tube senses pressure changes and moves the core of a differential transformer to change its electrical output. A simple, extremely dependable unit, built for many years of trouble-free service. Simple span and zero adjustments. Pressure ranges from absolute to 2000 psi.

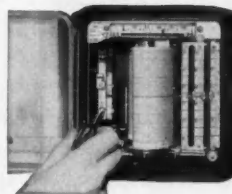
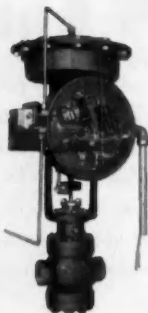
. . .

*See your Taylor Field Engineer
for full details or write for Bulletin.*

*Taylor Instrument Companies,
Rochester, N. Y., and Toronto, Ontario.*

VALVE POSITIONER

A true electro-pneumatic valve positioner, permits full utilization of the superior performance of electronic control, coupled with the power and smooth throttling action of pneumatic diaphragm motors. Pneumatic high-capacity, leakless booster relay is easily accessible for maintenance without exposing the electrical system. Unmatched stability due to powerful balanced armature reduces susceptibility to shock and vibration to a minimum. Designed for Class I, Group D, Division I areas.



1. Front Adjustments and all the features of the famous 90J Transcope Pneumatic Recorder. With chart, pen and set-point side-by-side (as in Transcope Pneumatic Recording Controllers) all pertinent process information

is immediately visualized. Hence operators make fewer mistakes. All available in one 6" x 6" cutout.

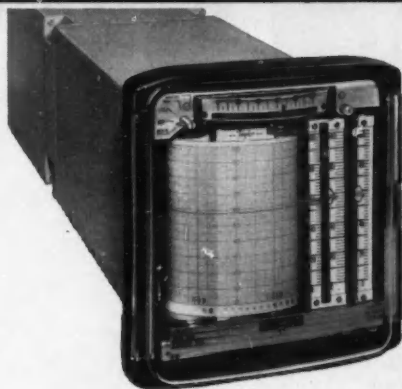
Taylor Instruments

sets new standards in

INSTRUMENTS

the highly successful TRANSCOPE* line!

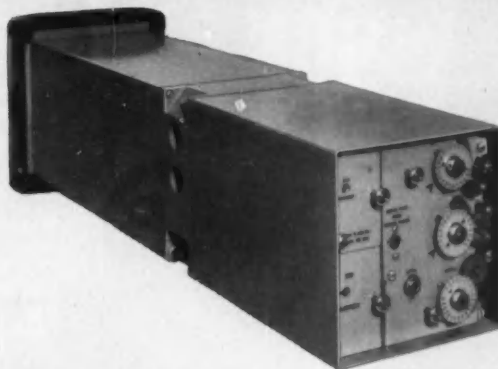
AC or DC RECORDER



Parallels electronically all the features of the TRANSCOPE Pneumatic Recorder that have won such wide acclaim. Positive, precise pen positioning provided by actual servo-motor, hundreds of times more powerful than meter type movement. Control settings and adjustments can be made from front or rear of case. Recorder can be removed without disturbing process control. Bumpless manual-to-automatic transfer is obtained without manual matching of set point and process. Plug-in Set Point Transmitter permits uninterrupted control.

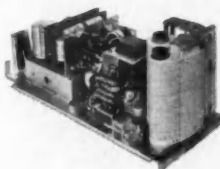
All transistorized (solid state), the 701J Recorder is unaffected by $\pm 10\%$ line voltage variation; thus there is no need for an expensive constant voltage source. All principal assemblies and sub-assemblies are plug-in type for flexibility and easy accessibility.

AC or DC CONTROLLER

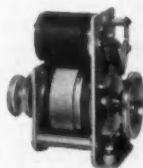


Embodies all the advantages of the most advanced control circuits. The unique diode limiter circuit permits even the two-response controllers to eliminate overpeaking on most applications. It is effective *at all times*, whether the variable is approaching control point from above or below; on changes in set point; following major process disturbances; or on start-up.

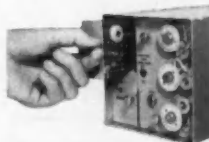
Interchangeable, plug-in assemblies permit conversion to either fast or standard reset and two-response or three-response controllers. Unparalleled rangeability makes this a universal controller. Unaffected by line voltage changes up to $\pm 10\%$. Controller signal gives multiple valve operation. Output signal from 1-5 Ma feeds into any load from 0-10,000 Ohms. Plug-in assemblies: control responses, operational amplifier, AC/DC Converter, DC reference supply and controller.



2. Interchangeable Recorder Slide. Completely transistorized. Unaffected by a supply voltage change up to $\pm 10\%$.



3. Powerful Servo Motor gives more precise pen positioning than ever before. More accurate records.



4. Plug-in Controller Sub-Assemblies. Printed circuit boards, mercury bottle disconnect switch.



5. Extremely Stable Controller Amplifier, utilizing latest design techniques and premium components.

*Reg. U.S. Pat. Off.

MEAN ACCURACY FIRST

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FEBRUARY 1959

17

First family of power triodes made specifically for series regulation!



Tung-Sol/Chatham power triode family covers every series regulator need!

Now designers can specify a premium quality Tung-Sol/Chatham tube for all series regulator sockets. Tung-Sol/Chatham's family of power triodes—the first designed and produced specially for series regulator service—meets all design requirements and assures maximum reliability and life at all times.

Types include the new 100 Watters, 7241 and 7242, medium mu or low mu-high current, 12 or 26 Volt

heater versions available on most types. All embody sturdy construction features that contribute to overall ruggedness and long hours of heavy-duty operation.

Compare the ratings below against your particular application! If you desire complete data sheets . . . or you have a specific design problem, contact us today! We'll be glad to give whatever assistance we can. Just write: Tung-Sol Electric Inc., Newark 4, N. J., Commercial Engineering Offices: Bloomfield and Livingston, N. J., Culver City, Calif., Melrose Park, Ill.

TYPICAL VALUES			
Total Plate Current	Range of Tube Voltage Drop	Minimum Tube Drop	Grid Voltage Swing
200 ma	80 v	45 v	20 v
400	65	70	10
600	80	70	13

PERTINENT CHARACTERISTICS PER TUBE			
Max. Plate Current	Max. Plate Voltage	MU	Gm
280	275	5.5	28,000 umhos
600	400	9.0	74,000 umhos
900	400	9.0	111,000 umhos

ts TUNG-SOL®

TUBE TYPES BY PLATE DISSIPATION RATINGS			
Total Plate Dissipation	26 to 30 W	60 W	100 W
	6AS7G, 6082	6336A	7241
	6080WA, 7105	6394A	
	5998	6528	7242

R. B. Colton

a geographer in GM's control lab

In General Motors' background operations for producing autos and other items, ranging from home appliances to locomotives, are many central staff technical groups. They serve as developers, consultants, occasional advisers, and assistants to divisional engineers wrestling with production and processing problems. One group has, since 1947, produced nearly 200 applications of electronics in processing, thousands of flexible packaged circuits that plug together to form control systems, and a set of electronic quality standards. The group is GM's Process Development Section, a beehive in constant search of the better way of doing things. Next to the heart of Process Development sits Staff Engineer Robert B. Colton, a 41-year-old geographer turned control expert, who is in charge of the 40-man Electronics Dept.

A dynamo who runs at top speed all the time, Colton aims to sell ideas and concepts, and then back them up with applicable hardware. Ultimate objective: to deliver more quality per car, refrigerator, diesel engine, etc.

Colton's idea of selling revolves around enthusiasm and good communications. His approach: present the problem, propose a pretested solution as dramatically as any pitch man. He has to, because any GM divisional engineer looking for help can—and often does—go to several other groups inside GM and elsewhere.

Control and how to sell it was far from Bob Colton's mind when he graduated from the University of Michigan. A major in geography, he planned to be an explorer. His first jobs were with geophysical companies. But during the war he suddenly found himself involved in work on merchant ships. Describing the denouement, Colton says, "Working on problems with gyros and steering gear gave me a feeling for control problems. When an appendectomy canceled a return to the seismograph, I did some soul-searching. I decided I needed to know more, to put down some roots, and to make some contributions."

Back on his feet, Colton headed for Michigan State College, where he taught while he earned an MS degree in physics. Then, in 1947, he joined



A hobby at fifteen . . .



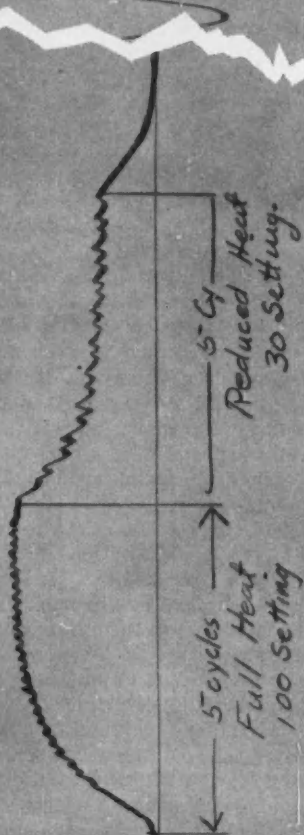
. . . turned into a career

GM's PDS, which had been organized a year before. His first assignment: to develop, practically overnight, a technique for gaging thickness of copper radiator stock. Later, forsaking the laboratory for administrative duties, he had more chance to teach, to sell, and just plain talk.

He was named chairman of a GM electronics subcommittee and joined forces with electronics men in GM research laboratories to develop GM's electronic quality standards, which may soon be adopted to supplement existing JIC codes. The new code (CtE, Nov. '58, p. 101) sets standards for ratings and specifications; components; physical construction; wiring, soldering, and other connections; instructions and diagrams; ventilation; and operating characteristics, including frequency.

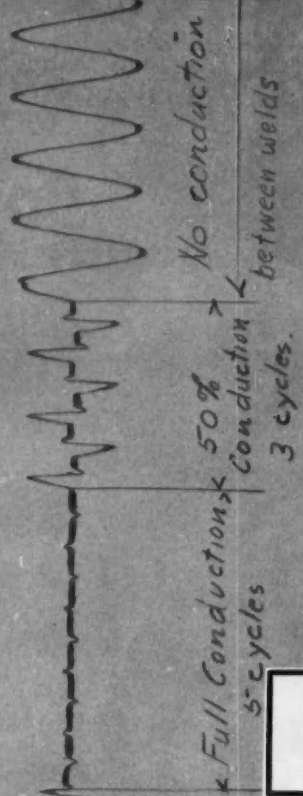
Current projects under Bob Colton's eye include nondestructive testing, machine control, information handling, and process applications. He hopes to make machine tools self-correcting to reduce tolerance ranges and to make running them from stored information more economical. And he would like to see existing computers adopted to cut down the long lead time for manufacturing development.

Colton becomes particularly enthusiastic when discussing his associates and how they attack a problem by the unwritten laws of creativity—a Colton predilection. He requires of them no particular specialization beyond good grounding in fundamentals, would prefer that they show evidence of creativity.



Oscillogram of Welding Current Pattern D.C.
 Taken from shunt
 in lower arm of welder.

Shows gradual build-up
 and decline of welding current.
 Essential in making
 good spot welds



Oscillogram taken
 across ignitron tubes.

this is a record



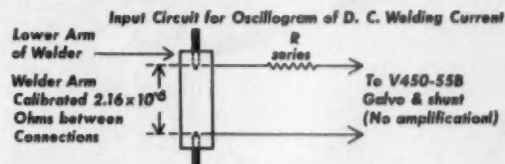
These welder phase-shift heat-control patterns were directly recorded with a Honeywell 906 Visicorder at Bristol Aircraft (Western) Limited in Winnipeg.

Since the welding heat generated is proportional to the square of the current value, phase shift must be accurately controlled in order to determine the heat value. If the phase shift dial is not accurately calibrated, the result is too much or too little heat, and a poor weld.

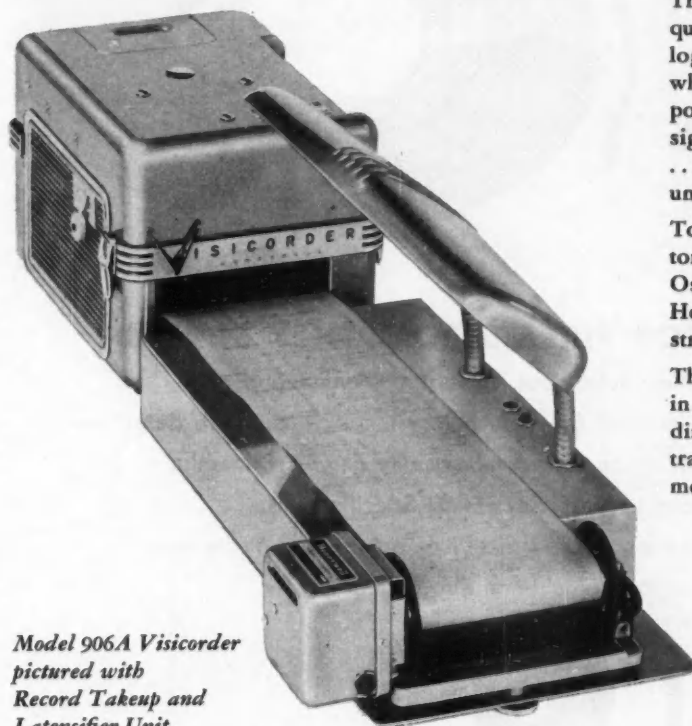
In this application, the Visicorder is an essential guide to accurate calibration, since ink-type re-

orders do not cover the sensitivities and frequencies needed and an oscilloscope would present a continually changing pattern since most recording periods are less than 10 cycles. The directly-recorded Visicorder patterns allow a convenient study of the exact time when the current wave form was being cut off.

Here is the circuit used in this test.



of phase shift



Model 906A Visicorder
pictured with
Record Takeup and
Latensifier Unit.

The Honeywell Visicorder is the first high-frequency, high-sensitivity direct recording oscillograph. In laboratories and in the field everywhere, instantly-readable Visicorder records are pointing the way to new advances in product design, rocketry, computing, control, nucleonics ... in any field where high speed variables are under study.

To record high frequency variables—and monitor them as they are recorded—use the Visicorder Oscillograph. Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

The new Model 906A Visicorder, now available in 8- and 14-channel models, produces longitudinal grid lines simultaneously with the dynamic traces, time lines, and trace identification by means of new Accessory units.

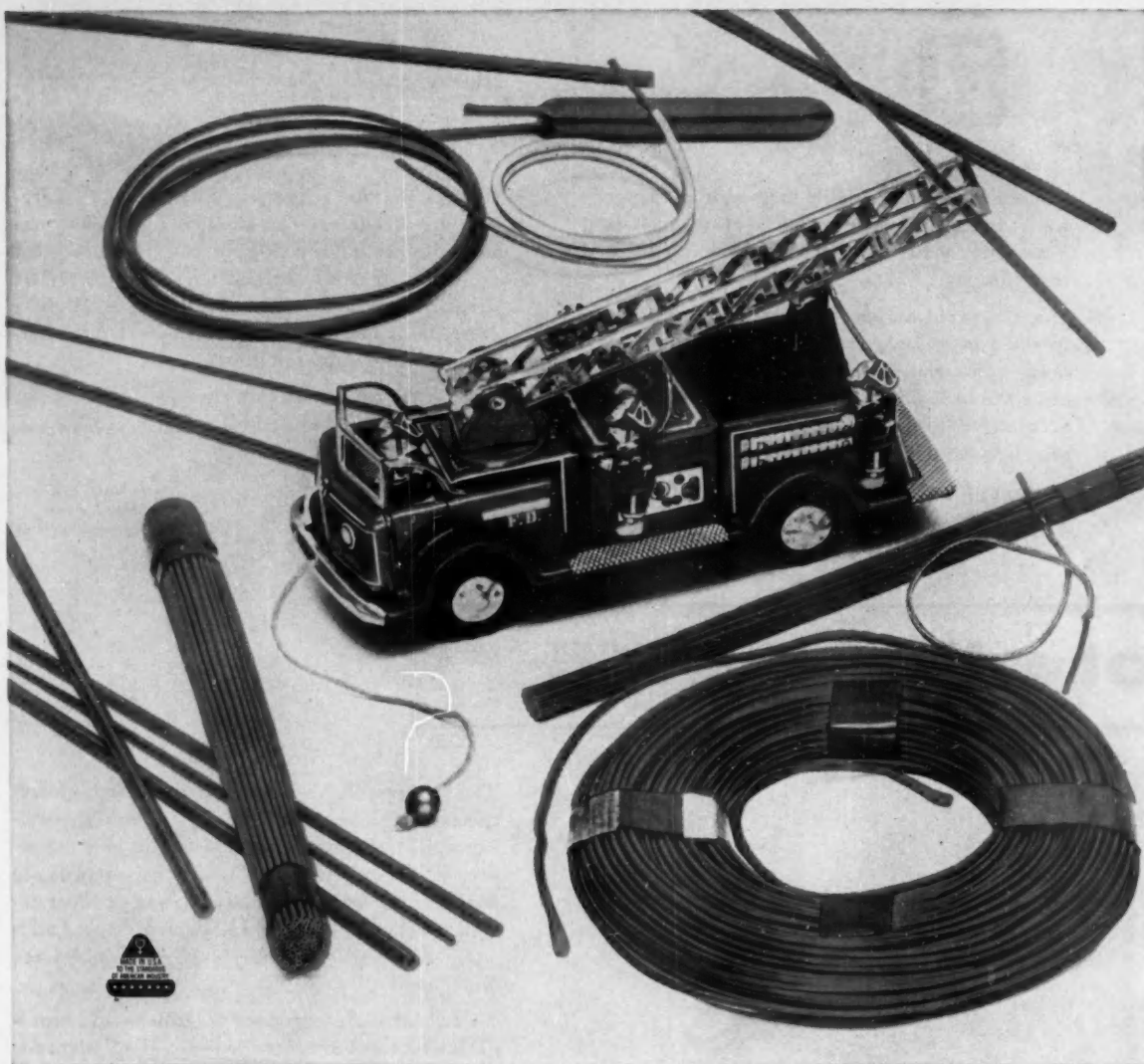
Reference Data: Write for Visicorder Bulletin

Minneapolis Honeywell Regulator Co.,
Industrial Products Group, Heiland Division
5200 E. Evans Avenue, Denver 22, Colorado

Honeywell



Industrial Products Group



KENSICO HELPS STOP FIRES BEFORE THEY SPREAD!

Kensico's precision-drawn copper capillary tube does just that—as an integral part of one of today's leading automatic fire detection systems. Effective fire detection and prevention of fire loss is dependent on overall tube quality and workmanship.

Close Tolerances. Inside Surfaces. Uniform Flow. Exact Specifications.

Tube Cleanliness. Why not try Kensico for your next small tube application? Write now for Free Flow Charts. Engineering Consultation also available.

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Kensico Tube

COMPANY INCORPORATED, MT. KISCO, N. Y.

Pinpointing Missile Strikes



IBM 709 computer takes over impact prediction from 704 machine. Greater capacity with newer tracking systems will mean smaller errors in estimating targets of long-range flights.

CAPE CANAVERAL—

Increased capability and flexibility have been imparted to the impact prediction system which tells the Cape Canaveral range safety officer where a missile will fall after launching if it is destroyed at any instant. A bigger IBM 709 computer has taken the place of the IBM 704 machine that had been performing impact predictions since March 1957. Additional tracking facilities are also being built.

• The changeover, completed in January, will keep Canaveral's tracking facilities up to date with missile progress. The 704 system had been geared to missiles with a 500-mile range. Despite almost continual improvement, it was hard-pressed to keep

up with such shoots as the successful 6,235-mile flight of an Atlas missile in November.

The greater capacity of the new machine is indicated by its 8,192-word memory (compared to the 4,096-word memory of the 704 computer). And the 709 completes a programmed cycle in 60 millisecc (the 704 required 85 to 90 millisecc).

• **Six tracking inputs**—The new 709 computer can accommodate inputs from six different tracking systems. The 704 machine handled one input at a time out of three tracking systems available. Although the 709 can process only four of the six inputs simultaneously, it can store all six, switching automatically to handle the input which at the instant is supplying the best geometric data for tracking. The 704 required manual switching from one tracking input to another.

When the new impact prediction system becomes completely operational, it will have these data-gathering devices:

► FPS 16 radar at Cape Canaveral;

high accuracy radar installation is to be completed by early 1959.

► FPS 16 radar at San Salvador, 600 miles down range from launching pads; installation in 1959.

► Azusa Mark I at Cape Canaveral—the breadboard system on which development was started eight years ago; has been used for impact prediction since 1957.

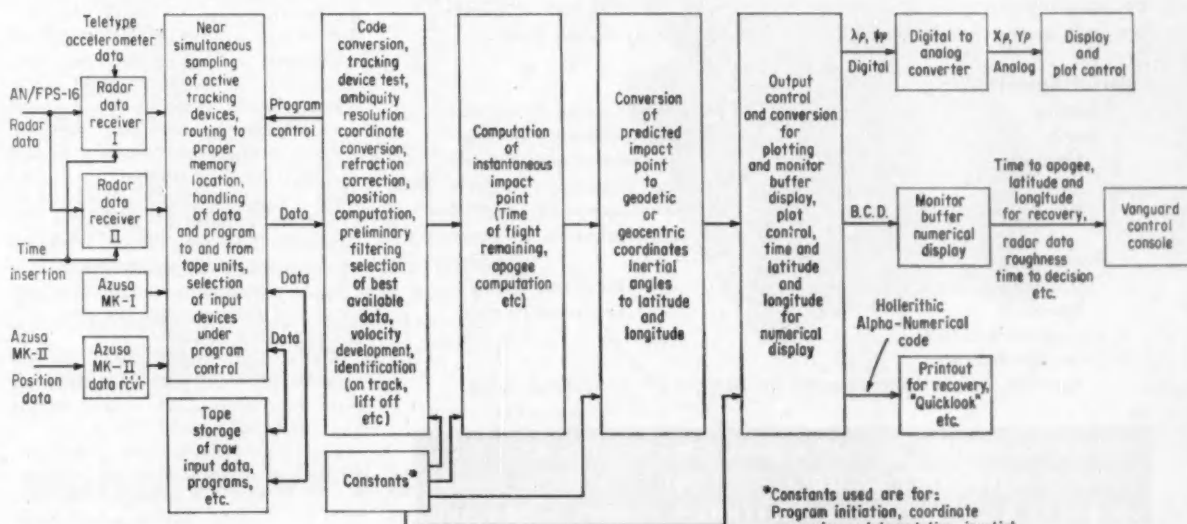
► Azusa Mark II at Cape Canaveral—a new, longer-range model with capabilities in the region of interplanetary distances; will be installed in 1959.

► XN-2 radar at Grand Bahamas Island.

► XN-1 radar at Patrick Air Force Base; this installation was the prototype of the accurate FPS 16 units.

Coordinates of the data received differ depending on the source of the information. The radars supply range, azimuth, and elevation; the Azusa provides range and two directing cosines. The computer converts all this data to a common denominator.

The 704 computer received inputs



*Constants used are for: Program initiation, coordinate conversion and translation, inertial computations, plot scaling, etc.

SWEEP RESOLVERS



MUIRHEAD

Muirhead have added the Size 23 Sweep Resolver type 23M7A1 to their wide range of synchros and resolvers.

The Sweep Resolver, designed for resolution of radar sweep voltages in P.P.I. displays, has the following features:—

Wide Band Operation: The flat frequency response of the 23M7A1, extending up to 100kc/s and peaking at 500kc/s, makes the receiver particularly suitable for accepting the time base waveforms met in radar sweep systems.

Compensator Windings: In addition to the two main windings the stator is wound with two compensator windings which can be used with suitable amplifiers to provide negative feedback and maintain proportionality between input and output voltage over a wide range of input voltage. In this way sweep linearities of better than 0.1% may be obtained.

Brief Specification:

Housing:		Standard Size 23 outline dimensions	
Stator:		2-phase with compensator windings	
Inductance	- - - -	Each main winding	17.0mH
		Each compensator	17.0mH
Resistance	- - - -	Each main winding	1.6 ohms
		Each compensator	5.0 ohms
Rotor:		2-phase	
Inductance	- - - -	Each phase	19.0mH
Resistance	- - - -	Each phase	2.6 ohms
Voltage rating at 1000c/s		0 to 30V	
Resolution Accuracy:		0-2% of max. voltage	
Maximum departure from sinusoidal characteristic		0-2% of max. voltage	

359

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CIRCLE 20 ON READER-SERVICE CARD

24

CONTROL ENGINEERING

WHAT'S NEW

... the safety officer can arm the destruct equipment and then let the 709 do the rest ...

from the XN-1, XN-2 radars and the Azusa system at the Cape.

• **Automatic destruct**—An example of the 709 system's increased capabilities is its performance in the "destruct" function. The range safety officer watches a missile's progress on the plotting board. As long as it behaves—stays within the destruct lines—he does nothing. If the missile obviously veers across the destruct lines, he destroys it. But if the missile strays from center and starts skirting the edges of the safe area, the safety officer can arm the destruct equipment in the missile and then let the 709 computer do the rest. When impact predictions indicate that the target will be missed and the missile will stray into areas which are not safe, the computer will automatically activate the destruct package aboard the missile, thus destroying it.

• **Error reduction**—Engineers at the RCA Service Co., who have developed the system, expect a gradual increase in accuracy of impact prediction with the new gear. The system using the 704 computer could predict impact of a 3,500-mile flight with a 20-mile error. RCA engineers hope the new system will eventually cut that error to three miles. It may even be reduced to a half-mile.

The increase in accuracy will be particularly helpful in recovery experiments. Missile experts point out that exact impact of an experimental missile is not too important—as long as the missile stays in safety territory. But if you are trying to recover an instrument package in the nose cone, you have to be able to pinpoint where it lands exactly.

• **Cost on the rise**—The increased accuracy will cost considerable. Rental of the IBM 709 computer will run about \$47,000 a month, compared to a monthly rental of \$33,000 for a 704 machine. The new Mark II Azusa system will cost \$4 million (the Mark I Azusa prototype is said to have cost about \$10 million), and the new FPS 16 radar \$1½ million.

The accurate impact prediction system may be the start of something even more significant. Using inputs from stations around the world, it would be possible to make global predictions of impacts of space vehicles.

—Douglas Dederer
McGraw-Hill News



DESIGN

As missile programs passed from early development to production, servovalves of increased sophistication became necessary. Keeping pace with this development, Moog has been responsible for all major servovalve improvements.

nozzle-flapper servovalves*

double-nozzle servovalves*

dry motor servovalves*

volume producer of double-nozzle
mechanical feedback servovalves†

*Patented †Patent Pending

MOOG:

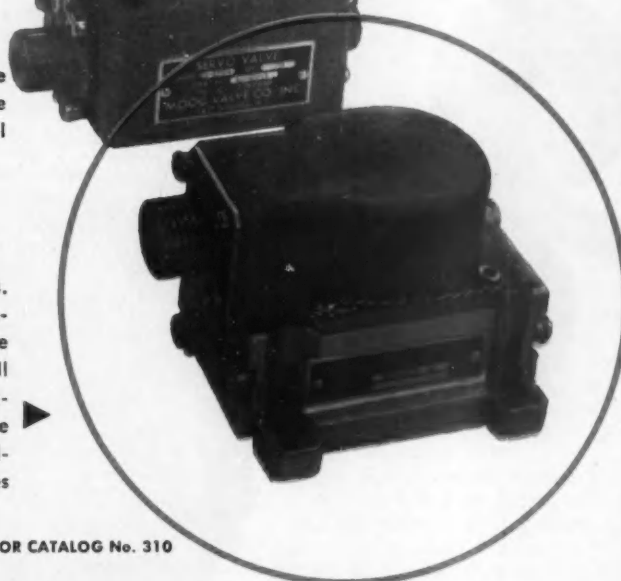
continued progress from

PRODUCTION

The 80,000 Moog servovalves produced to date represent a production record unmatched in the industry. Moog is the major supplier to virtually all missile programs.

RELIABILITY

Today reliability is the key requirement for missiles. Anticipating this need, Moog has had under intensive development and test for the past year the simplest, lightest, most compact and reliable of all production servovalves. Its performance in all important respects exceeds that of any other available unit. Moog is pleased to announce immediate availability of the new Model 31 and 32 Series valves in quantity to your specifications.



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And in operating **CONVENIENCE**, an "850" system provides such advantages as nine electrically controlled chart speeds, selected by pushbuttons ... a choice of interchangeable Preamplifiers (DC Coupling and Phase Sensitive Demodulator presently available, with others in development) ... remote control of chart drive, speeds, timer and marker ... monitoring connection points ... a Recorder that loads from front and has built-in paper take-up and paper footage indicator.

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(All data subject to change without notice)

Opcon Fills a Gap

An optimum controller moves into the void between conventional instrumentation and the digital computer for process control.



Two years ago, mathematicians at the Westinghouse Research Laboratory unveiled an electromechanical device called Automex (Automatic Experimenter) which was an attempt to duplicate human control of a process. To optimize a process, Automex continually changed the inputs, then measured the output to determine if an improvement resulted from the change. The method was much like climbing a hill, moving from one elevation to a higher one until a peak was reached. The mathematicians even used contour maps to explain how it worked.

Now an improved version of Automex, called Opcon (for optimizing control), has been applied to control the testing of capacitors at a Westinghouse plant. Another unit has been directing a miniplant for the dehydrogenation of ethylbenzene in the production of styrene at the Dow Chemical Co. since March 1958. A third unit will soon be installed on a full-scale distillation column at Sun Oil Co.'s Marcus Hook (Pa.) refinery.

The diagram shows how Opcon operates. It is really a special-purpose digital computer which makes yes-no decisions. The device sets input controllers at a value known to be reasonable. It then observes the output and compares it to the value

before the input change has been made. Next, the logic unit decides which variable or variables to change, how much, and in what direction to have the best chance of improving the output on the next move.

The rules by which Opcon makes the logical decisions as to its moves is called a strategy. Each process to be controlled requires a different strategy, and each strategy is designed into the transistor NOR circuits that make up the logic unit.

To use Opcon, a process engineer must have two pieces of information. First, he must know the two or three main input variables that influence output the most. And second, he must know the time it takes for a change in each to affect the output.

So far, Westinghouse has applied Opcon to control only two input variables. This, says Westinghouse Application Engineer William Evans, simplifies the hardware.

At the Dow installation, for example, reactor temperature and feed flow rate are the variables controlled to optimize output flow rate. Evans points out that the simplification has proved effective even though other inputs can change the output. He says the control can handle as many as ten or more inputs, but to do this, the device would require such exten-

sive and complex electronics that most of the advantage of Opcon would be lost.

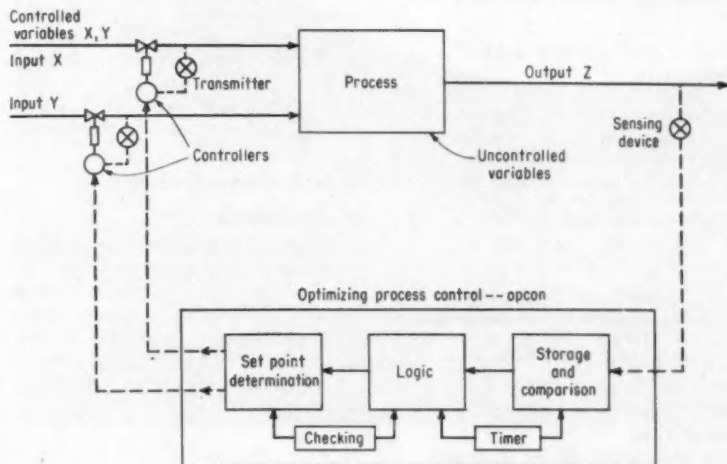
Evans feels that Opcon fits the needs of the chemical and petroleum industry better than general-purpose digital computers applied to optimize a process. He cites these three advantages: Opcon, with a probable price tag under \$25,000, costs much less than the digital computers already offered for process control; Opcon does not require knowledge of the differential equations which describe the process; as a special-purpose unit, the Westinghouse device is much simpler than a general-purpose computer, requires less maintenance.

Dow's John Bernard, who has watched Opcon work at Midland and feels the unit performed even better than expected, says it probably fits in the gap between conventional instrumentation and gp digital computers applied to process control. One benefit, according to Bernard, is that the control can be used to help explain what happens in a chemical process. By watching how changes in input variables affect output, process engineers receive some insight as to the mechanism taking place.

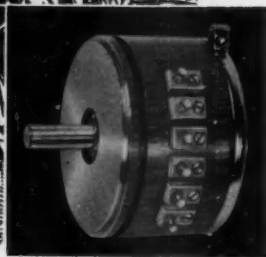
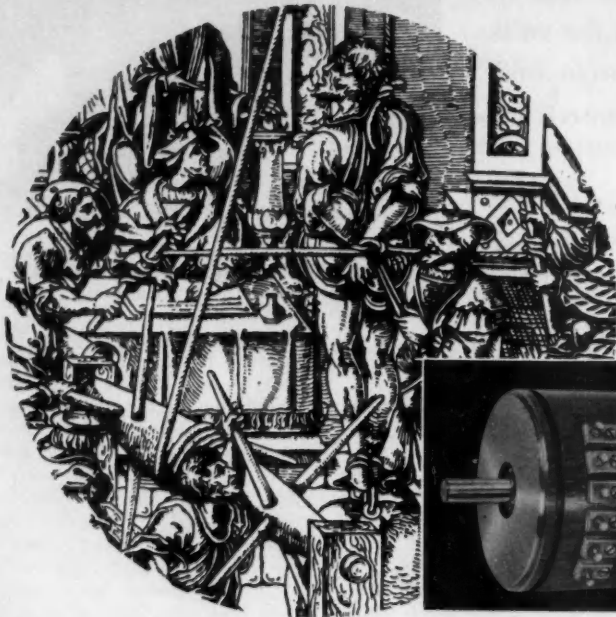
Based on the experience at Dow, both Evans and Bernard have also been introduced to some limitations of Opcon. Most important is the requirement that the output to be optimized must be measurable. In addition, anything that might fool a human operator is likely to fool Opcon. For example, if a sudden change in an "uncontrolled" variable were to offset the programmed changes, the optimum control would not recognize this as an external effect.

For the immediate future, Evans feels Opcon has its biggest application in optimizing "a portion of a plant", rather than tackling the whole process. He sees two or three units being applied to a process and then all being tied together somehow.

The flexibility of the control, Evans thinks, will make it usable in a variety



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CIRCLE 23 ON READER SERVICE CARD

WHAT'S NEW

of places. For example, its searching interval (the time between moves or changes in input variables) has ranged from 235 millisecc in the capacitor test unit to one hour in the Dow miniplant.

The installation planned for Sun Oil Co. will be a step in still another direction. At Marcus Hook, Opcon will maximize dollar profit from a distillation column.

PGAC Looks for Technical Papers

Professional Group on Automatic Control of the Institute of Radio Engineers is soliciting technical papers for the Automatic Control Conference, scheduled Nov. 4 to 6 at the Sheraton Hotel in Dallas, Tex.

Deadline for paper summaries is June 1. Four copies of the summary have to be submitted to G. S. Axelby, Westinghouse Electric Corp., Box 746, Baltimore 3, Md.

New Standards Group Joins NEMA

Manufacturers of industrial automatic systems have become the latest electrical product group to affiliate with NEMA (National Electrical Manufacturers Association). The new group will be known as the Industrial Automatic Systems Section. Chairman of the section is D. L. Pierce, Westinghouse Electric Corp.; chairman of the section's general engineering committee is H. L. Palmer of General Electric Co. Main job of the group at first: develop product standards for the industry.

Here are the products for which standards will be considered: assemblies of components arranged in one or more feedback-regulating closed loops to form a system for the measurement and control of industrial processes, such as but not limited to: 1) Machine tool and metal working machinery, 2) conveyor, automatic warehousing, and packaging machinery, and 3) mill processing machinery.

SAMA Sees Growth in Research

Today's \$7 billion investment in research and development should hit \$12.5 billion by 1962. That's what Kenneth Anderson, executive secretary of the Scientific Apparatus Makers Association predicts. In fact, Anderson sees R&D growing to \$21 billion by 1967.

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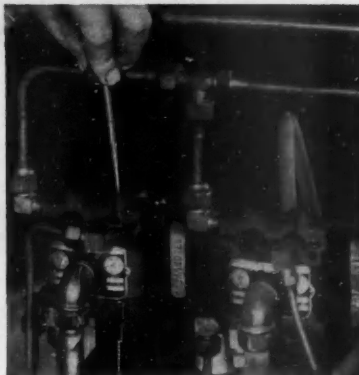
Why Skinner 4-way solenoid valves are used so widely for cylinder control



Application: A longitudinal and a transverse slide in this Pratt and Whitney Electrolimit Jig Borer is positioned automatically from numerical data on punched tape or manually by decade dials. When each slide has been correctly positioned it is held firmly by air-actuated, non-influencing clamps. Each clamp is controlled by a cylinder and a Skinner four-way V9 valve.



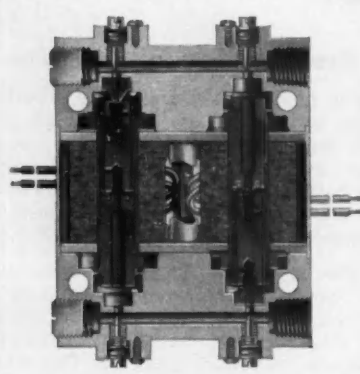
Features of standard valve did job. No special engineering of the four-way V9 valve was required to meet Pratt and Whitney's need. Molded oil-proof coils are used to guard against burnout from cutting solutions. The Skinner valve makes an ideal cross connection between electrical sensing and the muscular air required to provide the clamping action.



Dependable cylinder control. The four-way V9 valve is available with adjustable flow features in the main stream and in the exhaust passage for exceptionally accurate cylinder control. Position of inlet and exhaust connections can be changed easily in the field by simply reversing plugs.



Skinner V9 four-way valves, actually two 3-way valves in one housing are offered normally closed-normally closed, normally open-normally open, and normally closed and normally open. Media: air, inert gases, hydraulic fluids and vacuum; orifices: $\frac{3}{64}$ " to $\frac{1}{8}$ "; NPT ports: $\frac{1}{4}$ "; pressure ratings: to 250 psi. Over 350 basic variations.



Quality workmanship throughout. Internal parts are stainless steel and highly corrosion-resistant. Durable, compressible inserts of soft, synthetic materials insure bubbletight operation. Orifice seats have radius with well-rounded contact area and high finish for long insert life. Valve can be mounted in any position.



Exceptional life expectancy. Skinner valves, engineered to the highest UL standards, are life-cycled in the lab at speeds as high as 600 cycles per minute. In these tests, the V9 valves regularly get over 20-million cycles without leakage. And these results are constantly proving out in service.

Skinner solenoid valves are distributed nationally.

For complete information, contact a Skinner Representative listed in the Yellow Pages or write us at Dept. 342.

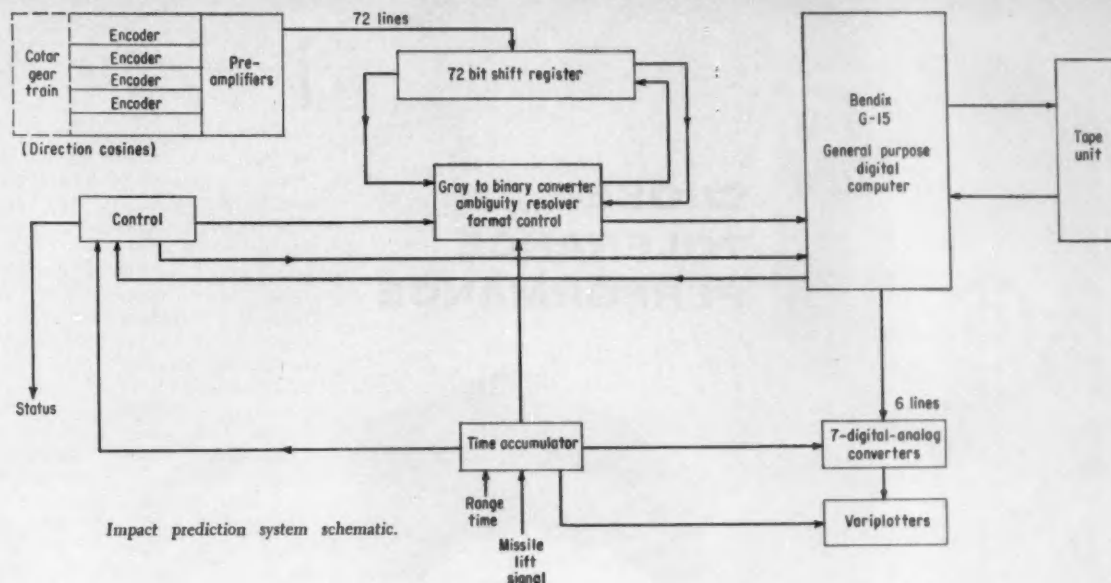


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Impact prediction system schematic.

Simplified Instrumentation at New U.S. Missile Range

Built primarily to train ballistic missile squadrons, the new Pacific Missile Range doesn't need the deep instrumentation used for R&D shoots. Still, it's a tricky exercise in how to use available tracking techniques while keeping costs down and instrumentation simple.

LOS ANGELES—

When a Thor IRBM blasted off and streaked out over the Pacific Ocean on Dec. 11, the U.S. officially had a new missile firing range. Primarily an operational facility, the Pacific Missile Range extends both seaward and inland. Long-range missiles can be launched 6,000 miles out over the ocean; an inland range reaches from the coast eastward over a thinly populated area to Dugway, Utah, and Tonapah, Nev. And since an unbroken, thousand-mile expanse of water lies between the launching sites and the south pole, PMR makes an ideal area for lifting satellites into north-south orbits.

Activities at the new range are divided between the Naval Missile Facility at Point Arguello (covering 20,000 acres but not yet ready for use) and Vandenberg Air Force Base (the

SAC facility that covers 70,000 acres). Vandenberg AFB will primarily train USAF missile squadrons. Point Arguello will be a tri-service facility, equipped and operated by the U. S. Navy but used by the Army, Navy, and Air Force.

Initial reconnaissance satellites—Discoverer series—will be launched from Vandenberg. But as soon as the Arguello facility becomes operational, the satellite firings will be shifted there. The Air Force base will then concentrate almost entirely on its training mission.

Instrumentation at the Pacific Missile Range mirrors its mission. It's far simpler than that used at Cape Canaveral because there will be few, if any, heavily instrumented R&D type firings at PMR. Aerojet-General, architects and engineers for Vandenberg AFB's Instrumentation and Range Safety System, have attempted to minimize instrumentation.

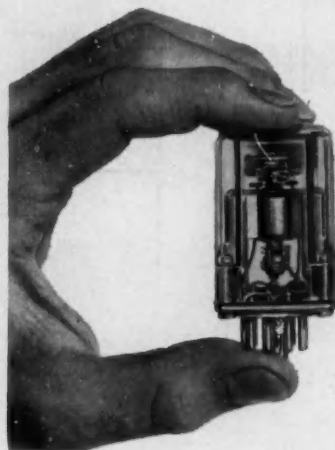
Vandenberg's instrumentation—Major instrumentation includes an operational surveillance system, a telemetry setup, and a timing system.

Surveillance is done with cameras. Three to five Mitchell high-speed 35-mm tracking units, depending on the visibility, are trained on the missile, to document external performance. Cine theodolites are also used.

From a fixed station in the instru-



Thor IRBM missile raised into position for first shoot at new Pacific Missile Range.



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The VHS measuring relay has the ability to differentiate between "normal and abnormal", "yes and no" on the basis of very minute electrical variations. In typical cases, it monitors 450 volts to $\pm 5\%$; in another, 14 microamps to ± 1 microamp.

Exceptional reliability and repeatability are achieved by the unique A.P.I. locking-coil design. At the point of contact, torque of the D'Arsonval movement is supplemented by the torque of the locking coil. Decisive switching action occurs with firm contact pressure. Contact resistance is low.

VHS measuring relays are available with high- and low-limit contacts, or either alone. Special models are available for excessive shock and vibration conditions.

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CIRCLE 26 ON READER-SERVICE CARD

CONTROL ENGINEERING

WHAT'S NEW

mentation control room the prelaunch monitoring of missile telemetry systems is performed and in-flight telemetered data is received and recorded. The timing system uses a 12-digit binary system.

Sensing device for the range safety system is an AME-COTAR (angle measuring equipment, correlation tracking and ranging system). A passive missile tracking system, it is used in conjunction with a Bendix G-15 general-purpose computer (see p. 31) as an impact prediction systems.

Here's how it works. Measurement is made of the phase difference of the rf signal transmitted from a missile's telemetering equipment as it is received at two different antennas, a known distance apart. At Vandenberg AFB, two cross-baseline antenna fields are used. The output information from each is presented as the cosine of two angles which are transmitted to the instrumentation control center via a servo-repeater link. The cosine information from both antenna fields is then introduced into the data processing system.

Data accuracy before transmission to the control center is expected to be on the order of 50 parts per million. Precise tracking will be limited to the line of sight—approximately 750 nautical miles—although azimuth tracking is expected to be accomplished over the horizon, limited only by signal strength.

The COTARS feed into the range's impact prediction system, which serves as the chief aid to the range safety officer, telling him where the missile will fall at any instant if it is destroyed at that instant. The system at PMR was built by Packard-Bell Computer Corp. at a cost of about \$300,000. The data is fed into a Bendix G-15 computer, then missile impact point and position are computed, presented on four plotting boards.

Packard-Bell is installing another impact prediction system at Arguello Point. This one will accept, in addition to COTAR data, radar information from RCA high-accuracy FPS-16 radars, proved at Cape Canaveral.

Missile squadrons have already begun training at Vandenberg Air Force Base. Launch, guidance, and maintenance teams will take their missile through a number of count-downs, finally completing their training with an actual launch. Then the troops will move out to operational bases. From time to time, they'll return for refresher firings.

—Michael J. Murphy
McGraw-Hill News

D.A. 1971

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WESTON ELECTRO- HYDRAULIC SERVO VALVE!



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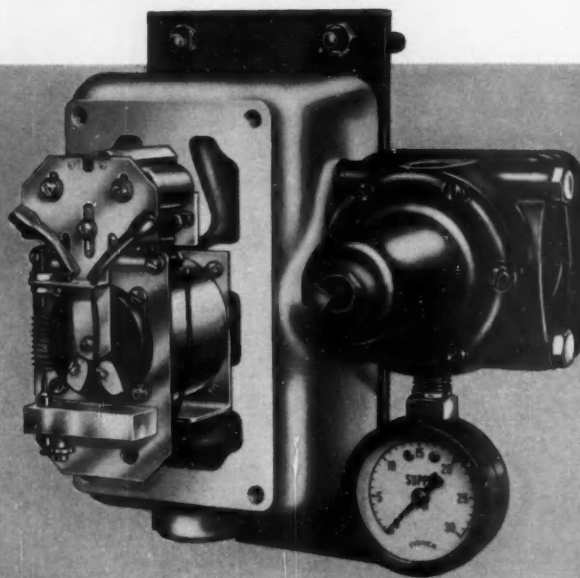
Ask Your **FISHER/MAN** How To SPEED THE INPUT SIGNAL to the CONTROL VALVE

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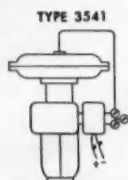
**ELECTRO PNEUMATIC
TRANSDUCER**



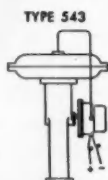
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Here's an electro-pneumatic transducer developed for use in electrical control loops where the final control element is pneumatically operated. Explosion proof design makes it ideal for use under hazardous conditions. Input signals may range from 1 to 5 ma. through 10 to 50 ma. ... output from 3 to 15 psi through 6 to 30 psi. Built-in volume relay permits direct operation of the pneumatic actuator from the Transducer. No extra relays or boosters needed. Relay can be serviced independent of electrical assembly. Unit is completely reversible by reversing input leads and rezeroing.

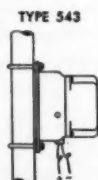
If you want additional information on the Type 543 Electro-Pneumatic Transducer write Fisher Governor Company.



TYPE 3541
Electro Pneumatic
Controller Mounted
on Control Valve



TYPE 543
Transducer Mounted
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TYPE 543
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TYPICAL CIRCUITS

Input Current	Load Requirements of Controller	Actual Internal Resistance of Transducer
1 to 5 ma dc	3,000 ohms maximum	2,500 ohms \pm 125 ohms
1 to 5 ma dc	12,000 ohms \pm .5%	12,000 ohms \pm 50 ohms
10 to 50 ma dc	500 ohms maximum	57 ohms \pm 4 ohms

PERFORMANCE DATA

Linearity.....1% of full range
Air Consumption Rate...2 SCFH with 15 psi output pressure
Resolution Sensitivity...0.05% of input range
Frequency Response....Complete frequency response data with Fisher topworks available



SINCE 1880

Purdue-CtE Conference: Putting Control System Components to Work in Industry

For the control engineer concerned with the application of components to industrial control systems, an unusual, working-level conference has been scheduled in May. Cosponsored by CONTROL ENGINEERING and Purdue University's School of Electrical Engineering and the Div. of Adult Education, the "Conference on Industrial Control System Components" will provide down-to-earth information on the application of electronic, hydraulic, and pneumatic components to control.

Site of the components conference will be Purdue's new \$8,650,000 Memorial Center, which will provide modern facilities for visual presentation of papers and demonstrations. The date: Monday and Tuesday, May 4 and 5, 1959.

Purdue's Dr. John E. Gibson and CtE's B. K. Ledgerwood have put together a program which emphasizes the practical aspects of control systems application. Areas to be covered include actuators, power amplifiers, transducers, and logic and decision-making elements. (For the final listing of papers and their authors, see the March issue of CtE.)

Typical subjects to be covered under actuators: high-performance dc motors, variable-displacement hydraulic pumps,

and power stepping motors. Included under power amplifiers: high-pressure pneumatic systems, mechanical amplifiers, and acceleration switching valves.

The session on transducers will hear broad coverage of the field. Some subjects: characteristics of position-measuring transducers, a survey of proximity switches, and measurements in hydraulic control systems.

Presentations about logic and decision-making elements will cover: solid state switching systems, the controlled rectifier for switching and power mod-

ulation, and components for automatic test and inspection systems.

Registration fee for the two-day conference has been set at \$35. Conferees will be housed in hotel facilities at the Purdue Memorial Union, which is adjacent to the Memorial Center. For technical information, contact Dr. John E. Gibson, School of Electrical Engineering, Purdue University.

For general information, write Merle M. McClure, Assistant Director, Div. of Adult Education, Purdue University, Lafayette, Ind.

CONFERENCE VITAL STATISTICS

NAME: Conference on Industrial Control Systems Components

SPONSORS: School of Electrical Engineering and the Div. of Adult Education, Purdue University; Control Engineering Magazine

DATE: Monday, Tuesday, May 4-5, 1959

LOCATION: Memorial Center, Purdue University, West Lafayette, Ind.

REGISTRATION FEE: \$35 (includes admission to all sessions, a copy of the proceedings, and a banquet dinner on Monday evening).

FOR INFORMATION WRITE: Merle M. McClure, Assistant Director, Div. of Adult Education, Purdue University, Lafayette, Ind.

Automatic Monitor Eyes Refinery Trouble Spots

La Gloria Oil & Gas Co. reports unexpected savings from a central monitoring system that scans variables in three sections of a gasoline plant.

DALLAS—

"Most of the benefits of an automatic data logger but at half the cost" is the way engineers at La Gloria Oil &

Gas Co. are describing a new central monitoring system which has been installed at the company's Falfurrias (Tex.) gasoline plant. The system monitors the casinghead gas compression section, high pressure gas absorption and compression section and a new ethane-propane recovery section. None of the distillation or fractionation sections are surveyed by the central system.

When planning the installation, La Gloria engineers considered the purchase of an automatic data logger. But

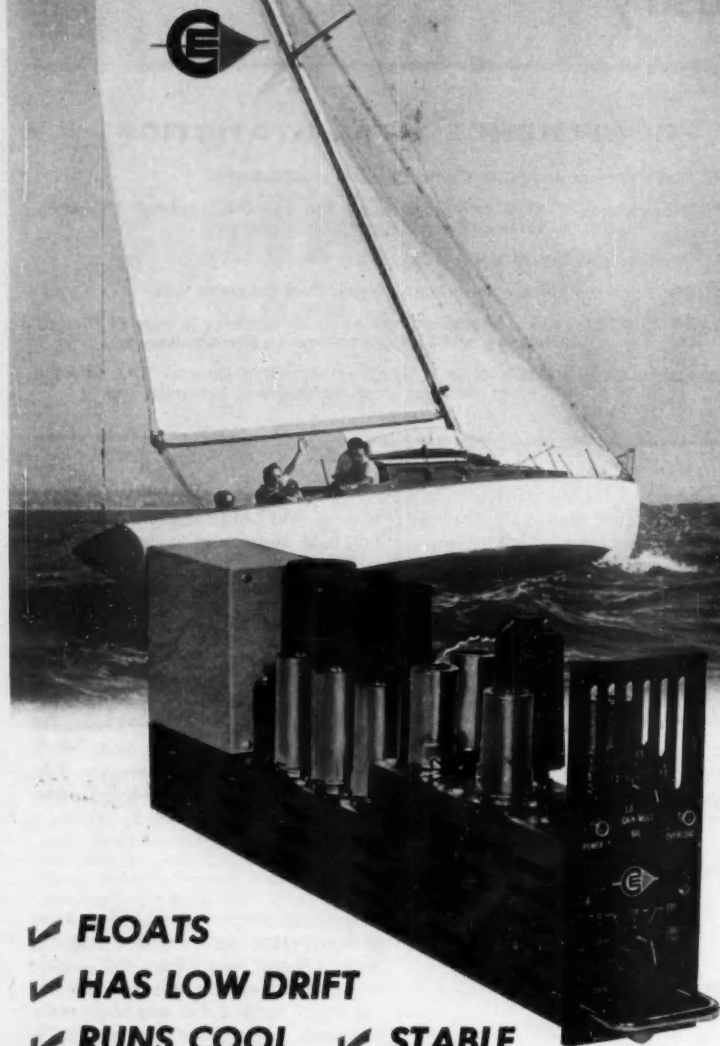
they found there were only four temperatures that really needed logging. Since a logger would have cost double the scanning system and the data was not really needed, the engineers compromised. The monitoring system is designed so it can be converted into an automatic data logging one if needed.

• **What's scanned**—One key part of the monitoring system is a 300-point temperature scanner engineered and built by The Foxboro Co.; it will operate at any speed from one to five temperatures per sec. Points scanned: 208 gas engine power cylinder exhausts, 103 gas compressor cylinder discharges, eight bearings on two centrifugal pumps, and three engine jacket waters. There are eight spare channels.

Also monitored are engine rpm and

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- ✓ LOW NOISE
- ✓ CONTINUOUS GAIN
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Write for Bulletin AI 132.1

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PASADENA, CALIFORNIA

ELGIN 5-7121

CIRCLE 29 ON READER-SERVICE CARD

WHAT'S NEW

lube oil pressure. These and engine jacket water temperature are considered "first out" variables. If any one of these on an engine is alarmed, it locks out the other two, thus signaling the exact trouble.

Moisture is monitored for three streams of gas, reading in pounds of water per million standard cubic feet of gas. Each stream is checked for one hour and moisture content is recorded at the central control house.

Dehydrators are also under surveillance. The three factors of interest: desiccant tower dehydrating, tower being regenerated, and the time both towers have been operating. Automatic switching valves on dehydrators are checked to report when a valve fails to function properly.

• **Temperature systems**—To connect all temperatures to the scanner, which surveys equipment spread over a five-acre area, required 9,600 ft of 12-pair thermocouple cable, 1,000 ft of eight-pair and 5,000 ft of single-pair.

Each temperature, measured by an iron-constantin thermocouple, has an individual alarm setting. Each is alarmed on the high side; 208 also sound an alarm if the temperature drops too low.

After an alarm is noted in the central control house, the operator contacts the man closest to the trouble by a bell signal system and a sound-powered telephone circuit.

In addition to the alarms, the temperature scanner uses a single indicator which, on demand, reports the temperature of the selected channel. All other indications are shown on pneumatic receiver gages. Pump and fan stoppages, liquid levels, and a few temperatures are alarmed on rectangular window annunciators. The indicating pneumatic receiver gages show various liquid and gas flows, pressures, and differential pressures. There is also one indication of feet of liquid in a 3,000-barrel surge tank.

• **Economic justification** — Homer Givens, plant superintendent at the Falfurrias operation, estimated it would take four years to pay for the monitor out of direct labor savings. By installing the monitoring system, La Gloria was able to install and operate the new ethane-propane recovery unit without hiring new employees, with the exception of one man added to the instrument department. (And only half this new man's time is chargeable to the monitoring system).

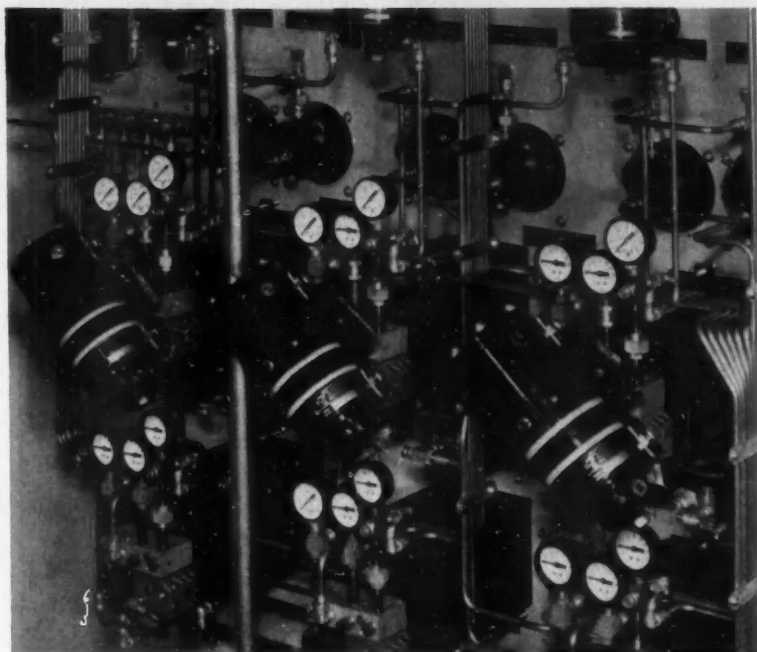
Now Givens thinks the payout period will be reduced. He says unexpected savings are accruing from the more efficient operation of compressors

IMPERIAL

Engineering and Data File



ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS



Leakproof connections quickly made with Hi-Duty tube fittings on Panellit control boards

Tube fittings that assemble to tubing fast and provide assurance against leaks are one of the top requirements for control boards.

That's why Panellit selected Imperial Hi-Duty fittings on this panel board used for automatically controlling a variety of oil refinery processes.

Hi-Duty Fittings have a one-piece nut and sleeve. A joint is made simply by pushing tube into fitting and tightening nut. Sleeve shears off and becomes permanent-

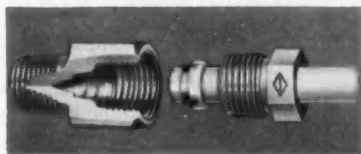
ly attached to tube. One man can easily assemble up to four Hi-Duty fittings in the time it takes to assemble one flare fitting. Hi-Duty assembles one-third faster than compression fittings and can be disconnected and reconnected repeatedly without leakage. And they withstand five times as much vibration as compression or flare fittings.

Write for Bulletin No. 3002

HOW HI-DUTY SAVES 36% TO 72% ON INSTALLATION TIME!

TYPE OF FITTING	AVERAGE TIME FOR EACH JOINT	JOINTS PER HOUR
HI-DUTY	11.7 sec.	307
Regular compression	18.5 sec.	194
Flare	48.2 sec.	74

These studies were made under actual shop conditions.



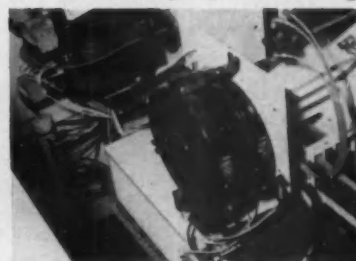
Disassembled Hi-Duty Fitting shows how sleeve has become permanently attached to tube.

IMPERIAL

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Poly-Flo fittings on color-coded tubing simplify servicing



International Paper Company service engineers enjoy simplified checking of 14-foot graphic control panels containing automatic and manual controls for operation of a complete pulp bleaching plant.

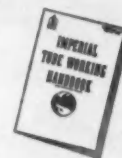
Polyethylene instrument loops are color-coded according to products. Nine tubing colors are available conforming to I.S.A. standards. Tube connections are made with Imperial Poly-Flo fittings.

In the event servicing is necessary, the engineer speedily disconnects and reconnects Poly-Flo fittings. No wrench needed... fittings need only to be finger tightened and joints stay tight.

Write for Bulletin No. 3025

Free handbook tells how to work with tubing

This practical book tells you how to cut, flare, bend, swage, ream and solder tubing... fully describes modern tube-working practice.



Handbook No. 369

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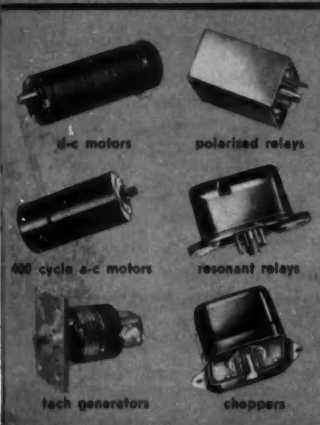
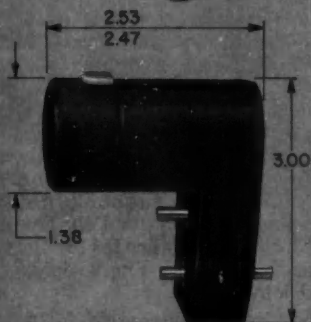
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multiple output motor
requires little space

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- Withstands sudden reversals
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CIRCLE 31 ON READER-SERVICE CARD

38

CONTROL ENGINEERING

WHAT'S NEW

and reduction in compressor down time. The monitoring system is catching trouble earlier—sometimes when it is still potential trouble.

• **Human reaction**—Givens says that his men like the system and have indicated they would not want to return to former operating procedures. Previously, monitoring was done by oilers as they made their rounds. It was a tedious chore. For example, including the new ethane-propane unit, the oilers would have had to check 576 compressor valve.

One reason for the good reaction by La Gloria's employees is that they had a part in the design of the system. When automatic monitoring was being considered, the employees were given details of the proposed system and heard the reasons for its installation. They were asked what equipment should be monitored and what information they needed.

La Gloria did all the engineering in this installation except the design work on the temperature scanner. The oil company bought all equipment for the cubic-type panels (except the scanner) and shipped it to Foxboro, which installed the gear in the cubicles and panels. Foxboro also designed and built the engine-compressor graphic panel, which indicates the particular part of the engine reporting an alarm.

—Kemp Anderson
McGraw-Hill News

EJCC Sees New Computers,
Hears Future Technology

The Eastern Joint Computer Conference this year saw the first public showings of significantly-new "big" general-purpose computers in recent years. And there were three of them:

IBM's new 7070—a transistorized system of modular design, can be installed with a capacity somewhat larger than the 650 series, and expanded as needed to handle the largest problems now practical. Control and processing units are new, fast, transistorized modules designed to make best use of IBM's input-output equipment—cards and high-speed tapes, and printers—as well as use additional core storage (up to 100,000 digits) and disc memories (RAMAC).

Remington Rand's New Univac Computer—a high capacity (50,000 characters) very-high-speed magnetic drum machine, uses Ferractor, transistor, and magnetic amplifiers in completely solid-state design that bor-

WHAT'S NEW

rows from the proven design of the Athena computer (discussed below). This new machine uses high-speed punched card input and output and a 600-line-per-min printer, and can read and punch simultaneously while processing in the central processor. Rental cost is \$6,950 per month. This is the first of a new line of low-cost Univacs. High-speed tapes will be available later.

RCA's new 501—a 16,000 character-magnetic-core machine in its basic version, is fully transistorized, even to the auxiliary input and output equipment. The core memory can be expanded to 260,000 characters, and the central computer can handle up to 63 tape machines. The basic 501 also has a 600-line-per-min printer.

This showing of new machines was properly in keeping with the theme of the conference—Modern Computers: Objectives, Designs, and Applications. Conference sessions were crowded. Over 2,600 had registered at Philadelphia's Bellevue-Stratford by the morning of the last day, and the registration desk was still busy.

• **Photo-etch memories**—About 1,000 persons heard the session on "The Impending Revolution in Computer Technology" at which Dudley Buck of MIT, inventor of the cryotron, described present research on computer memories, which sounds more like science fiction than fact. Buck said that he is satisfied it is feasible to "photo-etch" submicroscopic circuits, including the memory elements, by using electron optics to demagnify a diagram of the circuit. Such circuits can be built up layer by layer automatically, with insulating layers and superconductive magnetic shields between layers to form three-dimensional memories. Buck says low-cost memories with 5 billion bits per cu in. will be possible using such techniques.

The reliability session included a report on the performance of Athena, guidance computer for the Titan ICBM, by Remington Rand. Exhaustive studies were made on all types of components and efficiency of operation and cost were not considered important in their choice. Each component actually used in the fabrication of Athena was individually checked. The result is a large-scale (10,000-transistor) computer that has had only 27 failures in 6,000 hours of operation. Only five of these failures were components—all catastrophic. The rest were caused by wiring failures.

—E. J. Kompas

THE BARBER COLMAN QUALITY

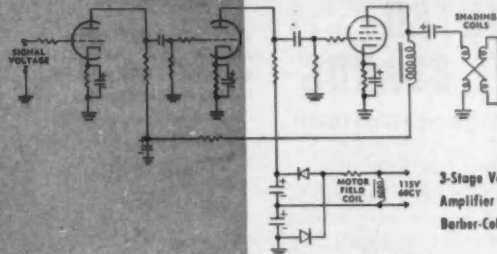
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Barber-Colman shaded pole reversible motors are adaptable to a variety of control circuits and power requirements up to 1/25 hp. They meet the specifications of many applications requiring a compact, powerful motor.



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Barber-Colman shaded pole motors are available with both enclosed and open gear trains. Wide choice of models with wide range of gear ratios.

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CIRCLE 32 ON READER-SERVICE CARD

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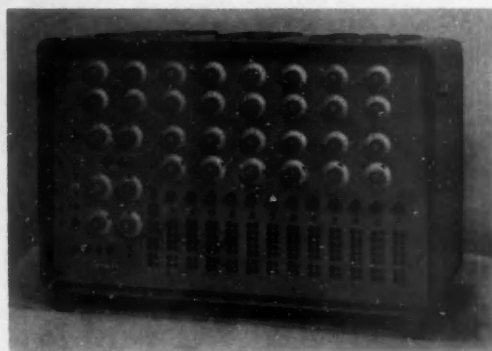
CONTROL ENGINEERING

EUROPEAN REPORT



Only numerical control system in production in Switzerland is transistorized equipment built by Societe Genevoise d'Instruments de Physique. Here it's applied to a jig borer.

Low-cost general-purpose analog computer was built by Guettinger Elektronische Rechengerate; 12-amplifier machine is said to be accurate to 0.3 percent; it sells for \$2,200.



Swiss Controls

... follow traditional Swiss engineering specialties. CtE's European editor sees major emphasis in power generation and turbine controls for export. Sophisticated machine tool control is just getting started.

BERNE—

Switzerland, the neutral island in Europe about one-third the size of New York, has built a first rate reputation as a supplier of precision instrumentation. But activity in the advanced aspects of control theory has been slow to develop. Now patches of advanced thinking and theory are starting to appear.

A few well-known companies supply 70 percent of the control industry's \$20 million annual output. They are: Brown Boveri, Sulzer, and Oerlikon in the heavy engineering field; Landis & Gyr, Fr. Sauter, and Amsler in process control; and Contraves, and the Societe Genevoise d'Instruments de Physique for machine tool controls. Specialized instrumentation is supplied by a dozen small firms such as Polymetron and Sigrist & Weiss.

• In the turbine field—Over 50 per-

cent of Swiss production is exported. West Germany, Holland, and Belgium each takes about a 10-percent share. The main Swiss control fields have followed the traditional Swiss engineering strongholds of turbine and compressor manufacture, power generation, and precision machine tools.

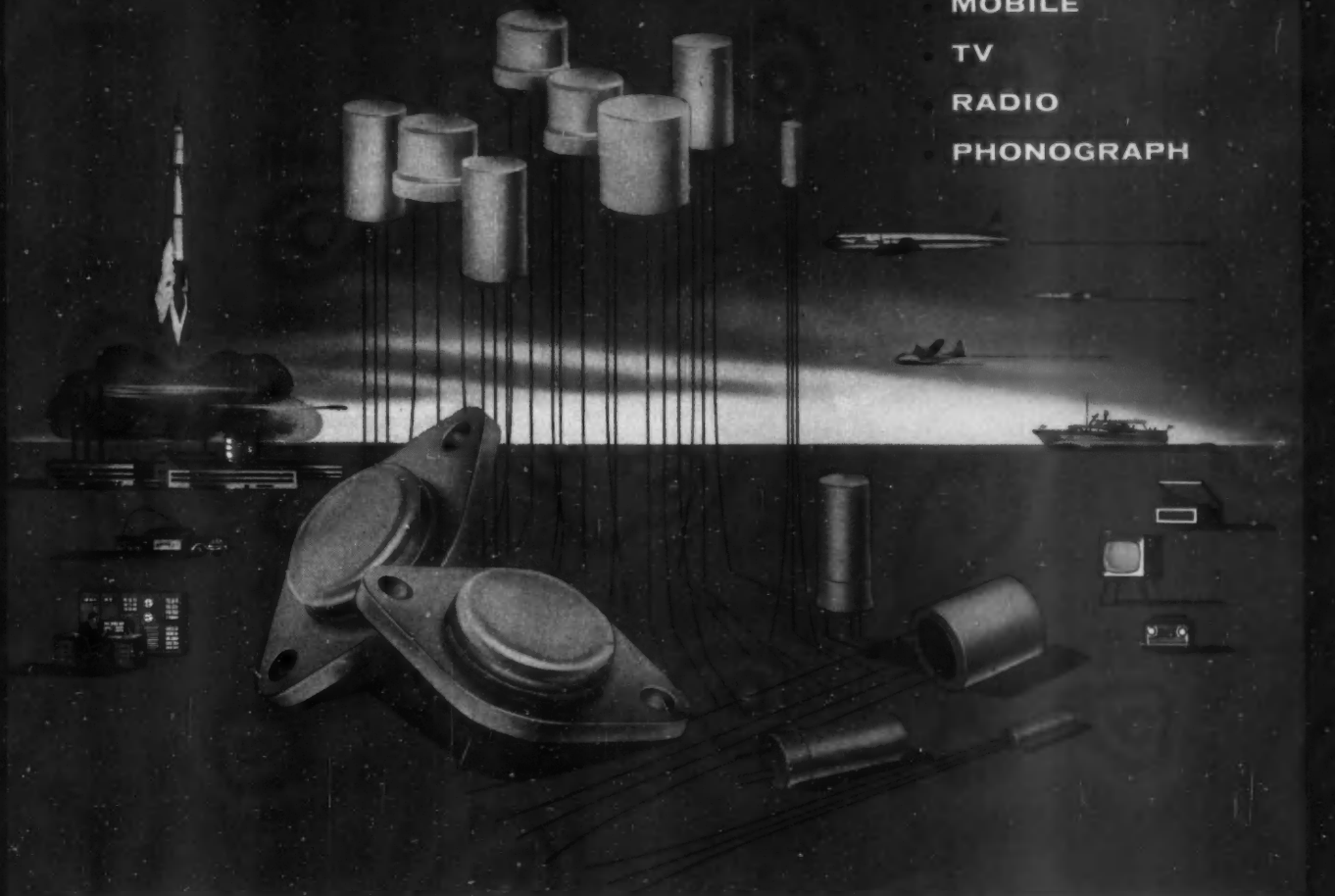
Brown Boveri, a leader in the turbine and compressor field, concentrates on hydraulic controls using its unique M-50 75-psi, two-term hydraulic controller. Inbuilt feedback links give a proportional band from plus 40 percent to minus 20 percent. Adjustable dashpots regulate the integral action time. A series of absolute and differential pressure transducers provides standardized 10 mm (0.394 in.) strokes to operate the controller.

Using the M-50, Brown Boveri is trying to increase the response speed of a new compressor anti-surge control

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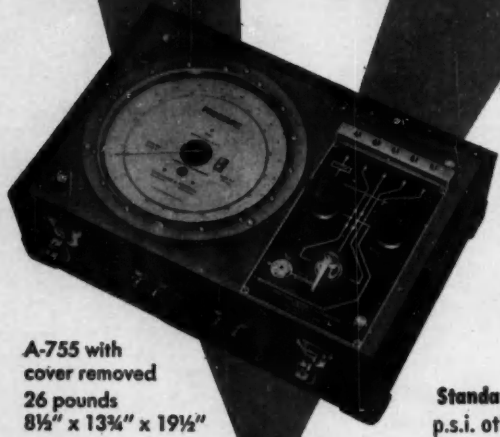
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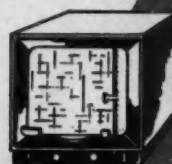
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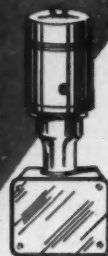
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WHAT'S NEW

**... only two numerical control
systems are known; one will
soon be seen in the U. S. . . .**

system. The problem is to compare inlet volumes and outlet pressures instead of inlet and outlet pressure ratios. At the same time, the controlling variable is switched between the output pressure and the compressor speed as compressor load varies. Response time of the new anti-surge blowoff valve would be around 1 sec, compared to the present 5 to 20 sec required by pneumatic systems.

• **Two numerical controls**—Although Swiss manufacturers have earned a world-wide reputation for precision machine tools, they have been reluctant to try numerical control. Only two systems are known.

Societe Genevoise d'Instruments de Physique is producing a record-play-back system. First models will soon be shipped to the United States. On a Hydroptic 6A jig borer, the transistorized system uses the same standard-length measuring scale for both manual positioning and automatic control. Fine position is obtained by photoelectric readoff of the standard scale after optical magnification. Synchros supply coarse position.

Position information is stored on three tracks of a magnetic coated cylinder. Two storage cylinders are running continuously. Changeover between the reading heads gives the operator a choice of up to 40 positions on each axis—to an accuracy of 0.0002 in.

A second system is still under development by Contraves A.G. of Zurich. It uses special punched cards, provides 20 positions per card for each axis. Synchros are used for both fine and coarse position; accuracy, 0.002 in.

More accurate systems are also under development. One of these will use the Contraves computing condenser as a position takeoff device.

• **Computer activity**—This same condenser was originally designed for the first Swiss analog computer. The machine contains 10 integrators, 40 multipliers, 10 dividers, 10 function generators, and 75 adders; it costs about \$50,000.

Aiming for the lower price computer market is Guettinger Elektronische Rechengerate (Niederteu-fen), a company which builds tailor-made, medium-size analog computers.

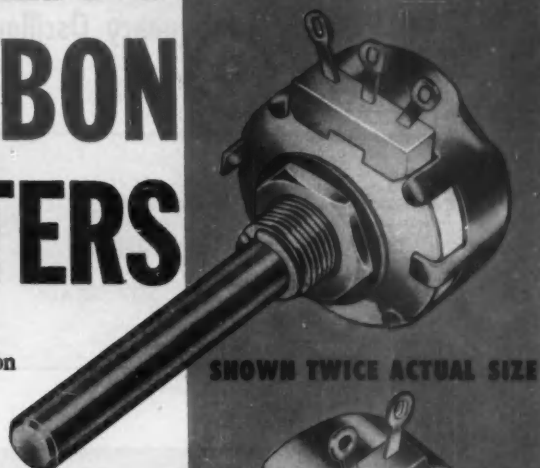
• **Simple process control**—Swiss engineers prefer to use simple equipment in process control applications. Typical of their approach: the two-term con-

HIGH RELIABILITY MOLDED CARBON POTENTIOMETERS

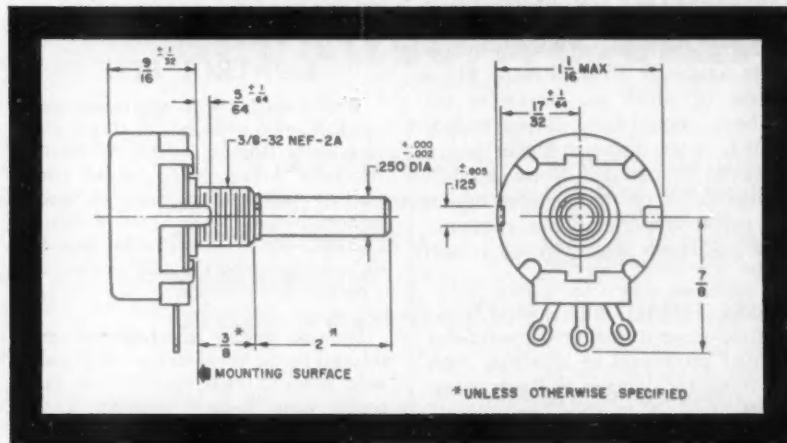
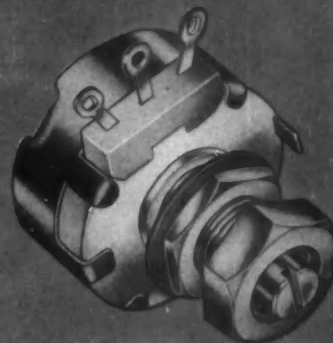
At long last, the radio-electronic industry now has another source of supply for molded carbon potentiometers. Years of Clarostat research and development, punctuated by countless tests in both lab and field, went into this product. And now you've got it.

Typically Clarostat quality, these are **superlative** carbon potentiometers. 2-watt rating. Meet all MIL-R-94 requirements for characteristic "Y" latest specifications. Make any comparison or test you wish!

Due to the variety of individual requirements, the specifications can be varied to meet your particular applications. Use Clarostat's engineering services. **Engineering data sent on request.**



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*Reg. U. S. Pat. Off.



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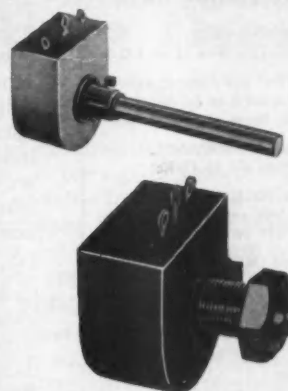
In Canada: CANADIAN MARCONI CO., LTD., TORONTO 17, ONT.

CIRCLE 35 ON READER-SERVICE CARD

FEBRUARY 1959

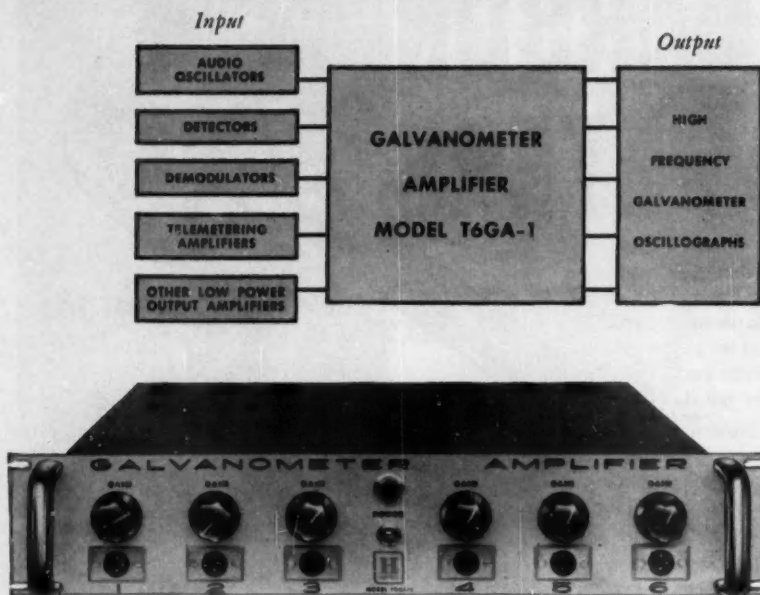
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As with other Clarostat potentiometers, these Series 53M molded carbon units are also available in "Potpot"* or encapsulated housings for maximum protection from all environmental conditions.



NEW GALVANOMETER AMPLIFIER

**Strengthens Low Power Signals
to Drive High Frequency Oscillographs**



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DESCRIPTIVE DATA

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Adjustable from 0 to 1.0

OUTPUT (37 OHM LOAD):
±2.4 volts at 65 ma d-c to 8 Kc, limits at ±100 ma.

OUTPUT IMPEDANCE:
2 Ohms d-c to 10 Kc

CONTROLS:
6 GAIN controls, 1 Power ON-OFF switch

INPUT IMPEDANCE: 47 K

ISOLATION:
Individually floating channels for use with ungrounded loads

NOISE:
Less than 3 mv peak-to-peak

DRIFT:
Less than 3 mv/°F

POWER REQUIREMENTS:
115 volts ±10 volts, 50 to 440 cps, 45 watts

With Honeywell's new Galvanometer Amplifier, Model T6GA-1, high frequency oscillographs can now be operated directly by low power input sources of 1 volt or more. These inputs, some of which are shown in the diagram above, should have output impedances of 10 K or less although higher source impedances can be tolerated. Noise and drift are indistinguishable on the recorded output when the galvanometer-amplifier combination has a maximum sensitivity of 1 inch per volt.

The Model T6GA-1 is a compact, six channel, three stage transistor d-c amplifier with overload protection to eliminate both danger of transistor damage and galvanometer burnout.

Each of the six amplifier channels is isolated from ground by individual floating power supplies. Write for Bulletin B-ET6 to Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston, Mass.

Honeywell



First in Control

CIRCLE 36 ON READER-SERVICE CARD

WHAT'S NEW

troller built by Fr. Sauter of Basel. The device has only one control knob, reset time. Proportional band and set-point are adjusted on the transducers. As a result, the controllers and transducers sell for about \$50 each.

Sauter has also built a transistorized two-term electronic controller which has operated with a deadband of 0.025 deg C on air conditioning gear.

Swiss users prefer to import more sophisticated instrumentation when it is required. The market totals about \$1 million per year. Almost half of the demand is supplied by European plants of U.S. firms such as Leeds & Northrup, Foxboro, and Minneapolis-Honeywell. German and English firms supply the rest.

• **Research in control**—Battelle Institute in Geneva (a branch of the Columbus, Ohio research organization), with some 300 people, is actively pursuing for European sponsors such projects as solid state switching for elevators and railroad control. Battelle's work also includes solid state variable speed drives for induction motors, digital-to-analog converters.

In Zurich, IBM maintains research laboratories specializing in hydraulics, ferro-resonance and phosphor investigation. RCA maintains a laboratory working primarily with solid state physics.

—Derek Barlow

CONTROL BITS

Rocket engine with one to one and one-half million pounds of thrust will be built by Rocketdyne Div. of North American Aviation, Inc., under contract to National Aeronautics & Space Administration. NASA Chief T. Keith Glennan expects it will take four to six years to design the giant engine, at a cost of \$200 million.

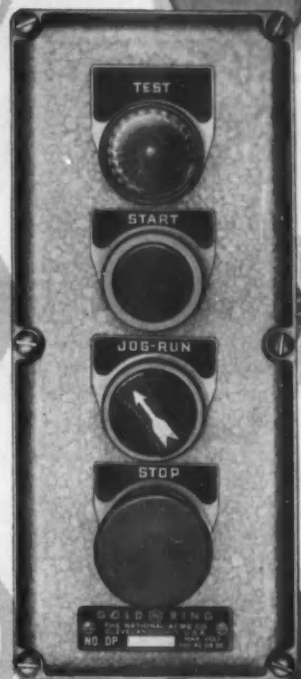
• **Infrared grating spectrometer**, developed by National Bureau of Standards, provides high resolution in the region from 3 to 6 microns, three times better than that available with the bureau's previous instrument. It makes possible detailed studies of molecular spectra, yielding data for the calculation of previously undetermined parameters for some of the larger molecules.

• **New Japanese parametron**, computer, with a floating-point system, has been installed at Tohoku University, 300 miles north of Tokyo. It's the first parametron machine that can handle 12-digit figures; previous units were limited to nine digits.

We build

better switches

because we can't buy them



**...IT'S AS SIMPLE
AS THAT...AND
THEY COST NO
MORE THAN
OTHER SWITCHES**

We had to build Gold-N-Ring Control Switches to meet our own high reliability specifications . . . our reputation was a part of this important fact. We're machine tool builders. We can't afford to be responsible for costly down-time on important capital investment equipment due to inferior control switches. That's why we build them like precise machine tools . . . and why it will pay you to check with us.

A wide range of basic units meets practically every need . . . as well as completely assembled stations in 1 to 4 button sizes to meet your electrical specifications. Ask our representative to call, or send for Bulletin ECS-56 . . . the complete selection and ordering guide.

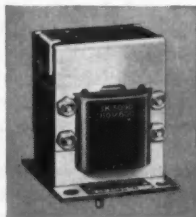
ELECTRICAL MANUFACTURING DIVISION

**National
Acme**

THE NATIONAL
ACME COMPANY
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CLEVELAND 8, OHIO

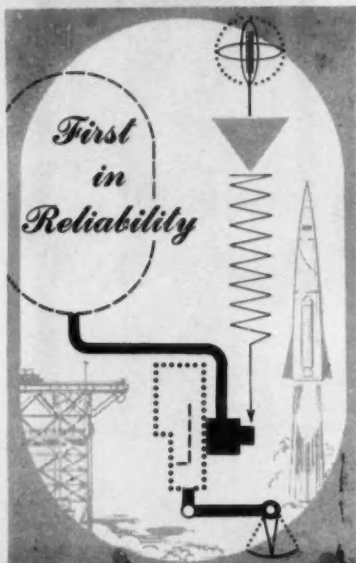


LIMIT SWITCHES. A full line, originally designed for machine tool applications but now used wherever the highest reliability factors are required. Bulletin EM-51.



SOLENOIDS. A full line of standard and custom units for AC or DC. Push or pull types with capacities up to 25 lbs. Bulletin EM-52A.

ATCHLEY electro-pneumatic SERVOVALVES



MODEL 610
Weight 11 ounces
Shown 1/2 size

Unique jet construction permits passage of particles as large as 200 microns through both the first and second stages without malfunctioning.

Other features include:

Single source of gas in first stage eliminates possibility of unbalance or "hard-over" signals due to gas contamination.

Second stage precisely controlled by a push-pull, frictionless, force feedback servo.

For more information, write for Data File CE-611-2.

Raymond Atchley, Inc.

2340 SANTELE BOULEVARD
LOS ANGELES 64, CALIFORNIA
TELEPHONE • GRANITE 9-8626

CIRCLE 38 ON READER-SERVICE CARD

46 CONTROL ENGINEERING

WHAT'S NEW

AROUND THE BUSINESS LOOP

Bringing Up a Company

An examination of the development of Controls Co. of America reveals the steps that have led to a successful and widespread operation.

A year ago last January, Controls Co. of America acquired Hetherington, Inc., of Folcroft, Pa., a manufacturer of high-precision switches and other electrical components for missiles, aircraft, and computers. Six months later, in June 1958, the Schiller Park, Ill., company acquired the Redmond motor group: Redmond Co. of Owosso, Mich., and Redmond Motors, Ltd., of St. Thomas, Ontario, Canada.

These were not the first additions made to its corporate family by CCA; rather, they reflected a continuation of a policy of healthy and careful expansion that in large part was responsible for a handsome sales record for CCA in 1957, the year the recession struck. Sales that year came to within 1 percent of what they were in 1956, or \$27,100,244, as compared to \$27,391,948.

Not only that, but earnings rose more than 12 percent to a new high (\$1,120,385).

• **Recession-tested**—This policy continues to pay dividends. In 1958, when the economy gave industry a 12-month taste of what it is like under a business slowdown, CCA could project an annual sales figure that wiped out the 1 percent deficiency of the year before and went beyond the 1956 mark to approximate a new record for sales of \$33 million. At the same time, it could make a longer-range prediction of \$37 to \$40 million for 1959.

But inherent in figures such as these must be, of course, more than just a good policy; there must also be a dynamic core. In CCA's case, this core is, or was, Soreng Products Corp., the result of the merger in 1953 of Soreng Mfg. Corp. and Sampsel Time Control, Inc. Both firms were experienced in R&D and production of control mechanisms, such as solenoids, timers, switches, modulating controls, rheostats, pressure regulators, shaded pole motors, and oil and gas regulators.

In 1956, two more companies, A-P Controls Corp. and Apco Corp., were merged into the organization. At the

same time, its name was changed to Controls Co. of America.

• **Access to the Coast**—Hetherington, one of the two latest acquisitions, today is operating as a wholly owned subsidiary under its own president, Joseph H. Schellman. It has plants at Folcroft and Sharon Hill, Pa., and El Segundo, Calif. One of the most important features of Hetherington, besides its products, is its location: it gives CCA easy access to the expanding West Coast economy.

Hetherington is particularly strong as a supplier of electrical components for missiles. Its products have gone into, among others, the Honest John, Douglas Genie, Nike-Hercules, Thor, Atlas, and Polaris.

Six-hundred and eighty Hetherington switches in its launching equipment helped get the Jupiter off to a successful flight.

The other new arrival, the Redmond group, has produced more than 70 million electric motors in 30 years. Consolidated sales have averaged more than \$12 million a year for the past five years, and net earnings have ranged from 2 to 7 percent of sales. It has 1,250 employees in plants in Ithaca, Mich., Jacksonville, Ark., Angola, Ind., and St. Thomas, Ontario.

James Tweedy, president of the Redmond group before its acquisition, continues at its head. In addition, he has been made a vice-president of CCA.

Other Redmond products besides 1/500 to 1/2 fractional hp motors: dynamometers, inverters, alterdyns, radar deflection yokes, gyro motors, and hand ring generators.

• **Far-flung**—Clearly, the word for the CCA operation today is widespread. Besides those cities already mentioned, it has plants at Milwaukee, Fremont, Ohio, North Manchester, Ind., Cooksville, Canada, Crystal Lake, Ill., Philadelphia, Santa Fe, N. M., and Nijmegen, Holland.

Its line of refrigeration and air conditioning controls is impressive. It includes thermostatic expansion and thermostatic by-pass valves, automatic expansion valves, water regulating valves, crankcase pressure regulating valves, evaporating pressure regulating valves, refrigeration system filters, refrigerant driers for refrigeration systems, and solenoid valves.

Top CCA officers include Roy W. Johnson, chairman of the board; Louis Putze, president; George D. Becker,

Tung-Sol moves ahead!

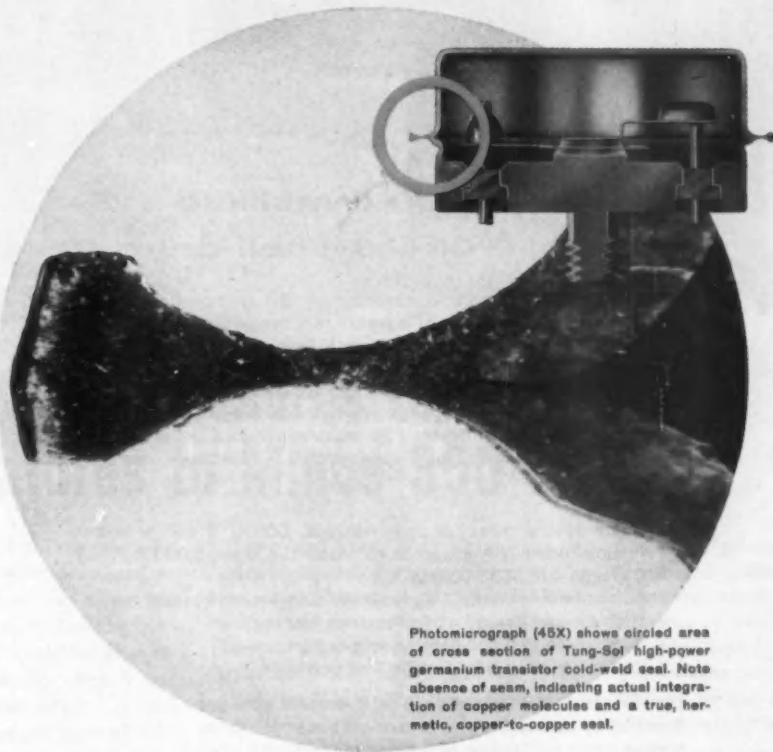
NOW

High power transistors with new **cold-weld** seal



**Improved cold-weld seal
gives new Tung-Sol
high-power transistors
three-way quality boost**

- True hermetic, copper-to-copper seal improves transistor thermal characteristics.
- Elimination of heat-damage, heat-caused moisture and "splash" increase reliability.
- Vacuum-tight, moisture-proof cold-weld seal lasts even through "breathing" over long life operation.



Photomicrograph (45X) shows circled area of cross section of Tung-Sol high-power germanium transistor cold-weld seal. Note absence of seam, indicating actual integration of copper molecules and a true, hermetic, copper-to-copper seal.

Once again Tung-Sol shows the way. Now, for the first time, Tung-Sol brings designers high-power germanium transistors with quality benefits of the advanced cold-weld seal.

The new Tung-Sol types feature a stud-mounted package and maximum collector current of 13 amps. Military environmental tests combine with the radioactive gas leak detection test to assure maximum reliability.

Technological advancements such as this keep Tung-Sol ahead of the field. For full data on the new high-power switching transistors . . . to meet any need with the latest in transistor design and efficiency, contact: Semiconductor Division, Tung-Sol Electric Inc., Newark 4, New Jersey.

 **TUNG-SOL®**

Improve Your Memory



with a standard multiple purpose off-the-shelf drum

The 512-A Bryant general purpose magnetic storage drum meets the exacting requirements of a production component, yet has the versatility necessary for laboratory work. This standard 5" dia. x 12" long drum is stocked for immediate shipment, complete with standard components such as general storage brackets, recirculating register brackets and magnetic read/record heads. Its low price reflects the benefits of Bryant's 25 years' experience in the efficient design and production of high speed precision spindles.

Features:

- Guaranteed accuracy of drum run-out, .00010" T. I. R. or less
- Integral drive - Bryant precision motor (1200 to 12,000 R. P. M.)
- Capacities to 625,000 bits
- Accommodates up to 240 magnetic read/record heads
- High density ground magnetic oxide coating
- Super-precision ball bearing suspension
- Vertical mounting for trouble free operation

Special Models: If your storage requirements cannot be handled by standard units, Bryant will assist you in the design and manufacture of custom-made drums. Speeds from 60 to 120,000 R. P. M. can be attained, with frequencies from 20 C. P. S. to 5 M. C. Sizes can range from 2" to 20" diameter, with storage up to 6,000,000 bits. Units include Bryant-built integral motors with ball or air bearings.

Write for Model 512-A booklet, or for special information.



Remember . . . you can't beat a Bryant drum!

BRYANT COMPUTER PRODUCTS DIVISION

BRYANT CHUCKING GRINDER CO.

P. O. Box 620-L, Springfield, Vermont, U.S.A.

WHAT'S NEW

vice-president and director of operations; Charles M. Stainton, vice-president and director of marketing; and Albert L. Topp, vice-president and director of sales and engineering for heating and air conditioning controls.

Also these vice-presidents: Stanley A. Johnson, director of Milwaukee manufacturing; Remy H. Ludwig, director of the International Div.; W. W. Mansfield, director of Schiller Park manufacturing; D. M. Strathearn, director of sales (appliance and automotive controls), and A. W. Elbert, chairman of the finance committee.

New Companies in the Field

Millard D. Shriver Co., Inc., a new California sales and engineering representative specializing in instrumentation and controls—in Alhambra, Calif. Millard D. Shriver, founder, is a former vice-president of Panellit, Inc.; his firm will handle such Panellit products as annunciators, control panels, and information systems. Lines of other companies will be announced.

Continental Device Corp., a semiconductor manufacturer headed by the former manager of the Semiconductor Div. of Hughes Aircraft Co.—in Los Angeles, Calif. The ex-Hughes man is Joseph S. O'Flaherty; with him in the new venture are James P. Hynes, vice-president; and Delbert M. Van Winkle, vice-president and technical director.

Power-tronic Systems, Inc., to develop and manufacture electronic computers, control systems, and components as a subsidiary of Hydra-Power Corp.—in New Rochelle, N. Y. Albert F. W. Parr, formerly head of the Systems Dept. of Norden Laboratories, is vice-president and chief engineer.

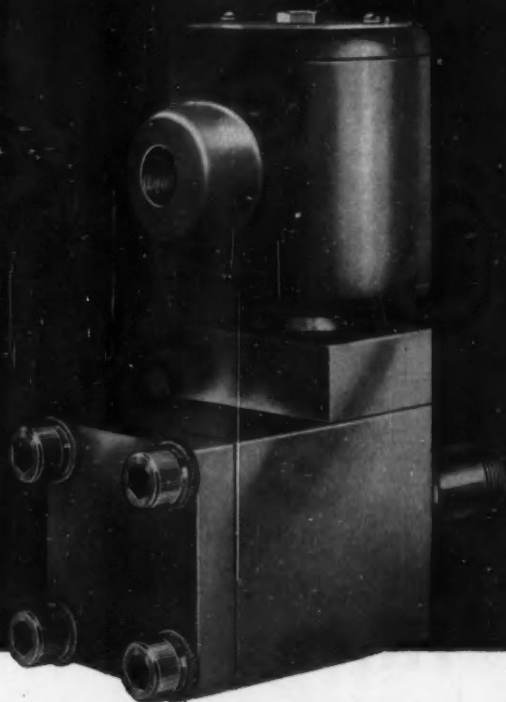
Flow Measurements Corp., which has acquired the flow meter business of Industrial Development Laboratories of Jersey City, N. J., and will continue to produce this line of thermal and ultrasonic units—in Kensington, Md. Albert L. Hedrich and Don R. Pardue operate the new company, which is closely associated with Weinschel Engineering & Mfg. Corp. of Kensington.

A joint venture (no name yet) by the U.S.'s General Mills, Inc., and Great Britain's Savage Ampersan Parsons, Ltd., to design and market-remote-controlled material-handling equipment for nuclear operations—probably in England. The British firm has been manufacturing this kind of equipment since 1954, and today

(Continued on page 138)

CIRCLE 40 ON READER-SERVICE CARD

ASCO SOLENOID VALVES ARE ENGINEERED TO MISSILE GROUND SUPPORT REQUIREMENTS

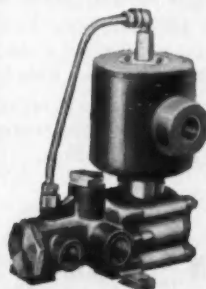


Tight Shut-Off at Pressures to 3000 PSI, Temperatures to Minus 350°F.

ASCO now brings you a family of solenoid valves, specially designed for missile applications with tough environmental or operational requirements. Two, three and four way valves are available with standard, explosion-proof or watertight solenoids; sizes range from $\frac{3}{8}$ " through $2\frac{1}{2}$ ". Fluids handled include air, liquid oxygen, helium and nitrogen (liquid and gaseous). Valves can be supplied with continuous duty coil windings for 24 volts D-C, and for any other commercial voltages required. All types are packless (hermetically sealed), providing tight shut-off, with no external leakage to atmosphere.

Two Way Valves . . . normally open or normally closed, easily handle fluids at pressures to 3000 psi, temperatures to -350° F. Valves are stainless steel with teflon discs; most sizes are available with AN connections (Main Illustration-Bulletin 8223X).

Three and Four Way Valves . . . are suitable for piloting cylinder operated valves. Three way valves are also utilized for controlling single acting cylinders, and diaphragms; four way valves are used for controlling double acting cylinders. Unique poppet type seats and discs assure tight seating at pressures to 750 psi, temperatures to -65° F. Valve shown below (Bulletin 8344X) is suitable for 4-way applications, or may be used for 3 way installations by plugging one cylinder connection.



Proposals are submitted upon receipt of specifications—or an ASCO Engineer can help you in solving your ground support valving problems.

For additional information on ASCO Solenoid Valves for Missiles, write for Publication V5056.

Automatic Switch Co.

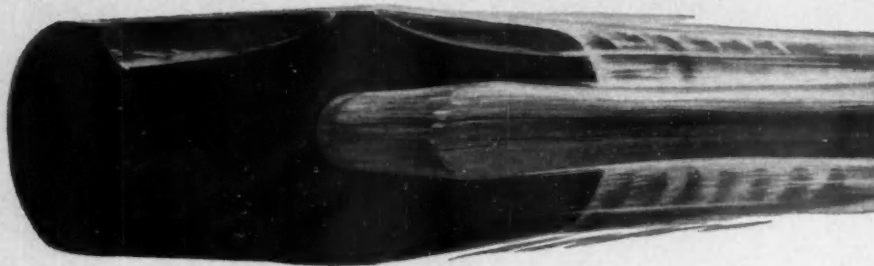
50-G Hanover Road, Florham Park, New Jersey • FRontier 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

CIRCLE 41 ON READER-SERVICE CARD

ASCO®

HOW MUCH SHOCK CAN



A SYNCHRO TAKE?

Improved Ketay synchros meet or exceed all the requirements of the new Mil Spec 20708, superseding all previous Mil Specs—including the drop hammer shock test, six blows of 2000 ft. lb. intensity, in horizontal and vertical directions.

Offering great accuracy and dependability, these Ketay synchros can perform faithfully under such severe shocks as explosion or recoil . . . in missiles or gun turrets, for example, or in submarines subjected to the impact of depth charges.

Stainless steel housing—far stronger than aluminum—and epoxy resin potting help make Ketay synchros rugged and shock-resistant. These and other design advantages also assure consistent accuracy despite extremes of temperature or moisture. Synchros of one or more sizes smaller and lighter than previously required can often be used because of their superior accuracy.

Ketay is the only source approved by the Navy Bureau of Ordnance currently manufacturing and shipping the new Mil-type synchros. Torque and control units (400 and 60 cps) are available in production quantities in frame sizes from 08 to 23 at no increase in cost.

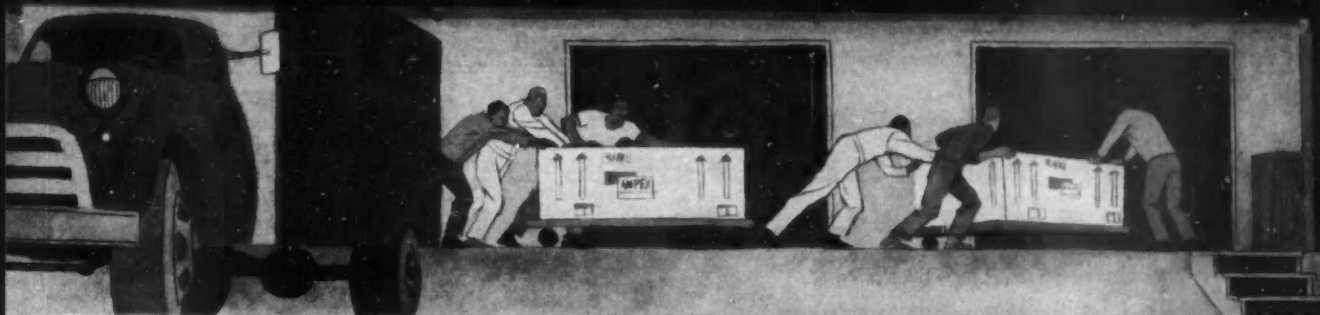
Ketay personnel are organized to work with engineers designing advanced prototype control systems. Call or write for help in solving your special problems.

*Ketay precision
components:*
SYNCHROS
RESOLVERS
POTENTIOMETERS
SERVO MOTORS
TACHOMETERS
SERVO AMPLIFIERS
GYROMECHANISMS
Catalogues available



*** NORDEN * DIVISION of United Aircraft Corporation**

KETAY DEPARTMENT, Commack, Long Island, N.Y.



Perfect complement to your AMPEX system



... your AMPEX Field Service Engineer

Ampex service begins the moment your new equipment comes out of the cases. Whether it is a single FR-100A or a complete digital tape handling system, your Ampex Service Engineer is there on installation day.

He sees to the proper installation of your equipment. He tests it with its original factory checkout tape and specially designed calibration units. And he thoroughly instructs your staff in its operation.

Throughout your warranty period—and afterwards—Ampex Field Service is instantly available for modifications or *fast* replacements, avoiding costly down time.

Minutes after your call to the nearest of 12 offices or to the Ampex Home Office, extra parts or components are on their way. And this same close tie between factory and Field Service keeps Ampex Service Engineers constantly up-to-date on the latest techniques and equipment.

Available are Field Service programs ranging from scheduled preventive maintenance calls or time and materials contracts, to the services of a full-time resident Ampex engineer. With your purchase, an Ampex data specialist will discuss a service and spare-parts plan tailor-made to suit your magnetic tape instrumentation needs.

First in magnetic tape instrumentation



AMPEX INSTRUMENTATION DIVISION
934 Charter Street, Redwood City, California
Offices in USA and Canada. Engineering representatives cover the world.

CIRCLE 43 ON READER-SERVICE CARD

HAGAN NEWSLETTER

Behind the Panel



AUTOMATIC DATA LOGGING FOR NATION'S FOURTH LARGEST WATER SYSTEM

A 158-year-old water works system, taking the first step toward full automation, is installing telemetering and micro-wave facilities to feed data from 92 remote locations throughout their 12 water districts to a Hagan Kybernetes Data Handling system installed in a central building—the Load Control Center. The data includes such items as: water levels, river elevations, pumping rates, pumping pressures, water flow, and other information to provide an operator at the Load Control Center with an instantaneous picture of events throughout the whole water works system.

High and low limits for every point can be fixed from the central system and such off-normal conditions as unexpected level changes, distribution pressure drop, rise in river height will be detected by visible and audible alarms from the Kybernetes system, as well as red printing on the log sheets where the data system is recording all the variables. Normal operation calls for print-out every hour, but it may be obtained at any time—as well as printing special continuous readings on any point experiencing off-normal conditions. Hagan also furnished the main control console and a graphic wall panel. (Item B-1)

HIGH EFFICIENCY DUST COLLECTOR PAYS FOR ITSELF IN TWO WEEKS

Uranium dust in the atmosphere at a uranium ore reduction plant had become an irritating air pollution problem—as well as a source of loss of the valuable ore dust. A Hagan Aerostatic Dust Collector was installed at the rod mill in the plant and has been operating at 97.7% efficiency—recovering so much uranium dust that it paid for itself in two weeks. The collector has shown no signs of wear or tube plugging. In fact, one plant official said, "This is the first mechanical collector I have ever come across that is actually self-cleaning." At another installation where blast furnace slag dust is being collected, the Hagan unit was inspected after 15 months' service. More than 160 tons of abrasive dust had passed through the tube that was cut in half for examination, yet no wear was visible. In fact, most of the mill scale was still intact. (Item B-2)

METER ACCURACY TEST . . . $1 + 1 + 1 + 1 = 1$

The odd looking formula above refers to a utility installation where Hagan Ring Balance meters are in service for all principal metering. The first four figures represent four Ring Balance meters which measure these flows: 6th extraction stage, 9th extraction stage, 12th extraction stage and condensate. A fifth meter measures steam flow to the turbine. In other words, the fifth meter measures steam before the turbine while the totals of the other four meters represent steam recovered after the turbine. Ideally, these totals would be the same. At the end of a nine month period the sum of the four meters was compared to the total recorded on the fifth and the figures were within 2.4% of each other, despite the fact that more than three-quarters of a billion pounds of steam had passed through the system over this period. (Item B-3)

SUPER-SONIC MISSILE TESTS IN LESS THAN 30 SECONDS

Snap a huge valve open in a fraction of a second—let a 3000 mph gale blow through for a few seconds—keep this supersonic hurricane constant in a test chamber—all this in less than 30 seconds. Next, volumes of data from brief tests like this are analyzed to know, in advance, if your missile or aircraft is ready for flight. This is what happens in a blowdown wind tunnel where Hagan PowrAmp control systems meet and exceed rigid specifications for split-second accuracy and reliability. At one blowdown tunnel where PowrAmp transducers, amplifiers, computers, electro-hydraulic pilot valves and operators are installed at critical control points, the tunnel was "blown in" for its first test without aid from Hagan engineers, who were available, but were not needed after the PowrAmp equipment had been installed and adjusted. (Item B-4)

HAGAN CHEMICALS & CONTROLS, INC.

Hagan Building, Room 701, Pittsburgh 30, Pa.

If you would like more information on any of the above items, check the appropriate box below.

☐ Item B-1

☐ Item B-2

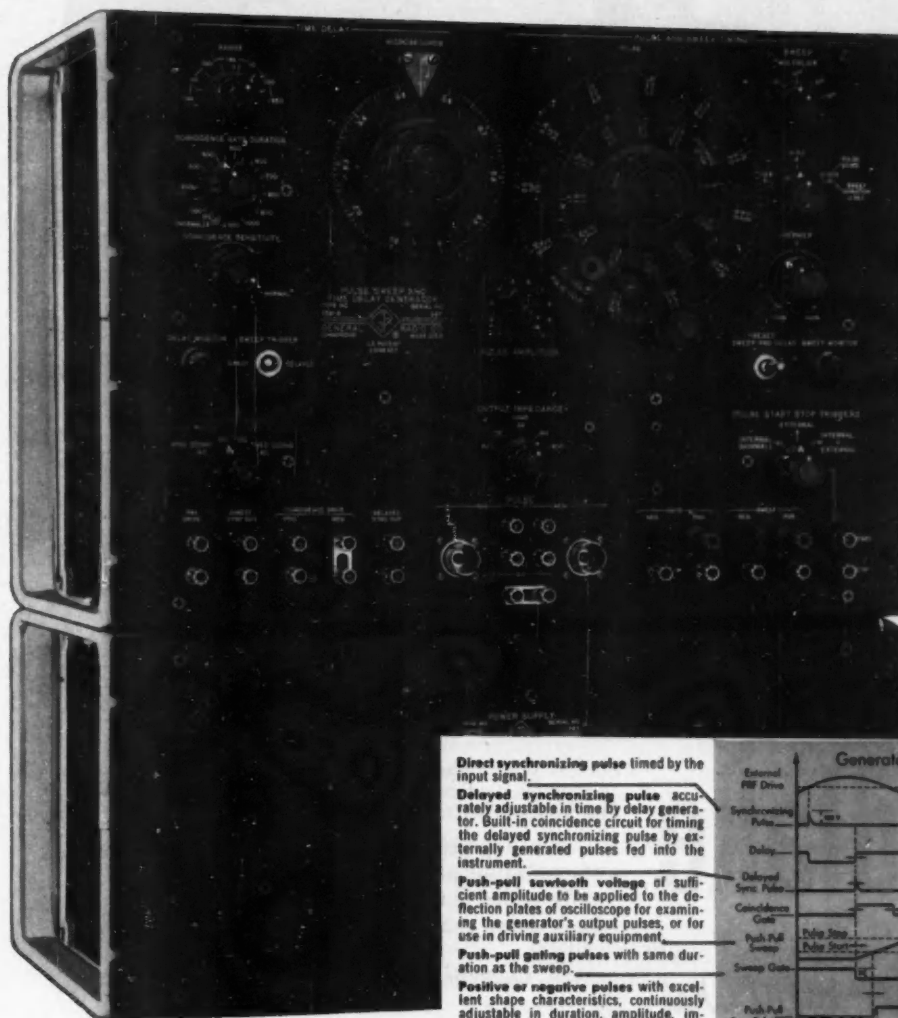
☐ Item B-3

☐ Item B-4

COMPLETE, ACCURATE, WIDE RANGE Time Measurements and Pulse-Waveform Synthesis

One Instrument for ...ECHO RANGING, TELEMETERING, COMPUTER DESIGN, TELEVISION,
RADIO NAVIGATION, AND PHYSIOLOGICAL RESEARCH.

Type 1391-B PULSE, SWEEP and TIME-DELAY GENERATOR, \$1975



- ★ **Fast Rise and Decay Times — Better than 0.015 μ sec**
- ★ **Push-Pull Pulses with Durations from 0.025 μ sec to 1.1 sec.**
- ★ **Time Delays from 1 μ sec to 1.1 sec.**
- ★ **Linear Sweep Voltage from 3 μ sec to 0.12 sec.**
- ★ **NO Duty Ratio Restrictions.**
- ★ **Very Small Jitter and Overshoot**
- ★ **High Accuracy and High Resolution Throughout.**
- ★ **Circuits Stable Against Hum and Line Transients.**
- ★ **Coincidence Circuitry For Multiple Pulsing and Time Selection.**
- ★ **Variable Output Impedance for Correct Termination with Variety of Transmission Lines.**
- ★ **Extreme Versatility — Panel Controls for Important Pulse Characteristics. Binding Posts Provide Ready Access to Sync Pulses, Gates, Delayed Signals, Pulses, and Internal Sweeps.**

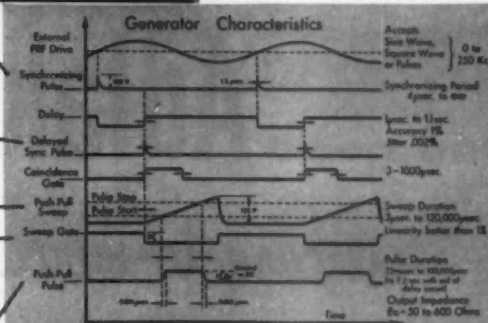
Direct synchronizing pulse timed by the input signal.

Delayed synchronizing pulse accurately adjustable in time by delay generator. Built-in coincidence circuit for timing the delayed synchronizing pulse by externally generated pulses fed into the instrument.

Push-pull sawtooth voltage of sufficient amplitude to be applied to the deflection plates of oscilloscope for examining the generator's output pulses, or for use in driving auxiliary equipment.

Push-pull gating pulses with same duration as the sweep.

Positive or negative pulses with excellent shape characteristics, continuously adjustable in duration, amplitude, impedance level, and delay with respect to (a) the direct sync pulse and (b) the sweep.



Write for Complete Information

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Abington, Pa.
HAncock 4-7419

WASHINGTON, D.C.
8055 Thirteenth St.
Silver Spring, Md.
JUniper 5-1088

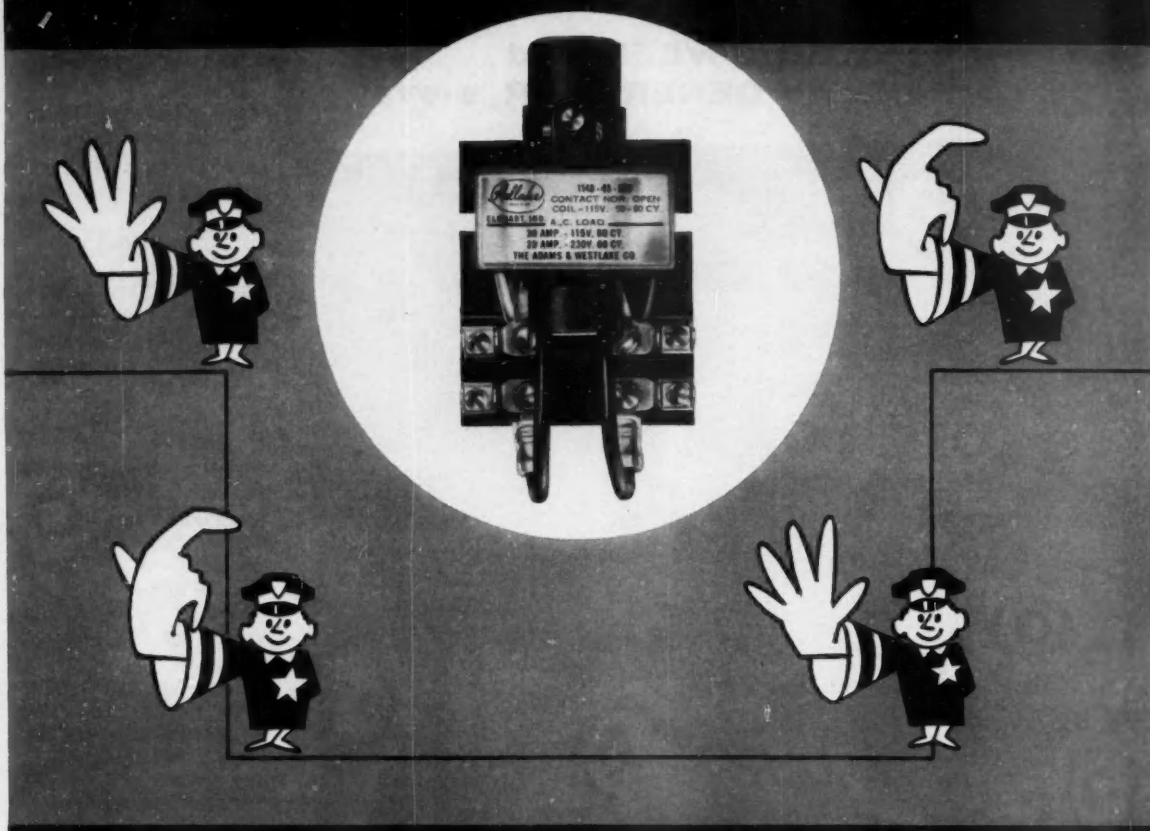
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Los Altos, Cal.
WHitecliff 8-8233

LOS ANGELES
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Los Angeles 38, Cal.
HOLlywood 9-6201

IN CANADA
99 Floral Pkwy.
Toronto 15, Ontario
CHerry 6-2171

CIRCLE 45 ON READER-SERVICE CARD

When You Need Reliable Control of Intermittent Operations...



you need **Adlake** *mercury-to-mercury* **relays**

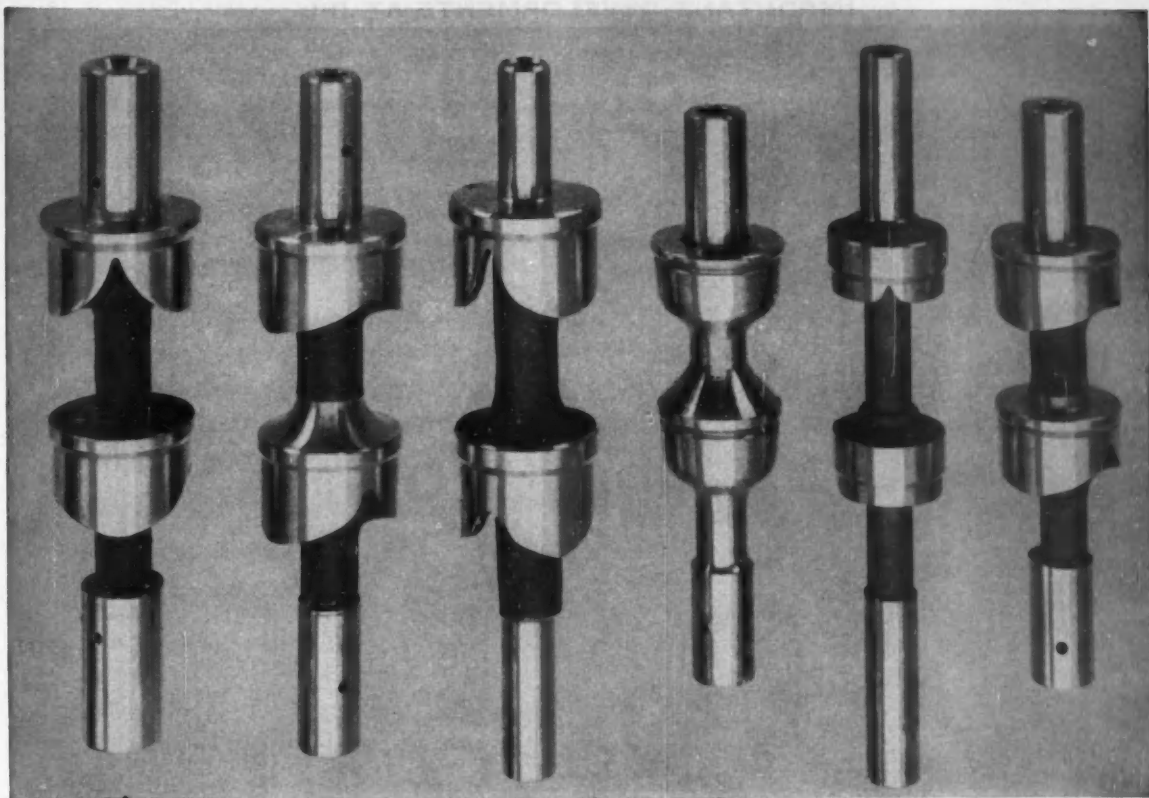
Set up your requirements for the perfect relay to "police" a particular job—and beyond doubt you'll find yourself with this list of Adlake features:

- Perfect snap-action—no burning, pitting or sticking
- No intrusion of dust, dirt or moisture—hermetically sealed at the factory
- Time delay characteristics fixed and non-adjustable
- Quiet. Chatterless. Require no maintenance whatever

Our engineers will gladly help you with your control problems. No obligation. Just write the original and largest maker of plunger-type relays—The Adams & Westlake Company, 1181 N. Michigan, Elkhart, Indiana • New York • Chicago



The Adams & Westlake Company
NEW YORK ELKHART, INDIANA CHICAGO
Established 1857



Inner secrets of inner valves

FACTS EVERY CONTROL VALVE USER SHOULD KNOW

This is a rare photograph . . . presented in a completely unretouched form. It shows the inner valve of leading makes of diaphragm control valves. The inner valve determines the control result.

The most amazing fact is the size . . . all are listed as two inch valves. All are high lift. But compare them.

Note the KIELEY & MUELLER inner valve at the far left. It equals the others on every point of con-

sideration; exceeds on many. Look at the diameter across the skirt . . . that's one reason for the remarkable C_v of K&M valves. Look at skirt length; the solid, not fabricated, design. Measure the rugged guide posts and the large column. Examine the machining and the super-finishing.

It's no wonder . . . K&M is the valve that likes to be compared. It's a better valve and a better value by every measure of comparison.



FOR THE COMPLETE FACTS . . .
write for the K&M Valve Engineer-
ing Data Catalog, Bulletin CV53.

diaphragm control valves

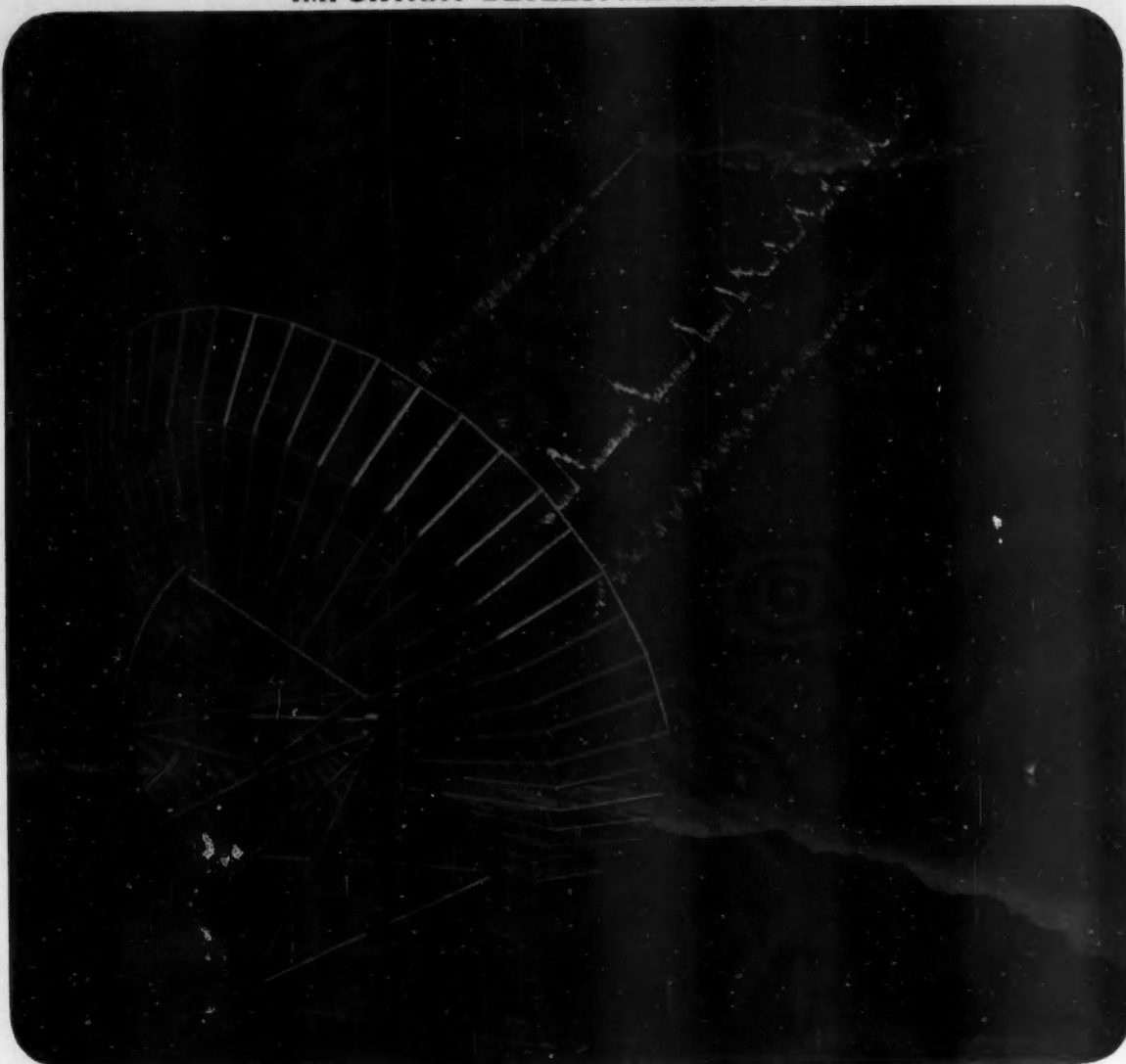
K&M

Our 78th Year

KIELEY & MUELLER, INCORPORATED

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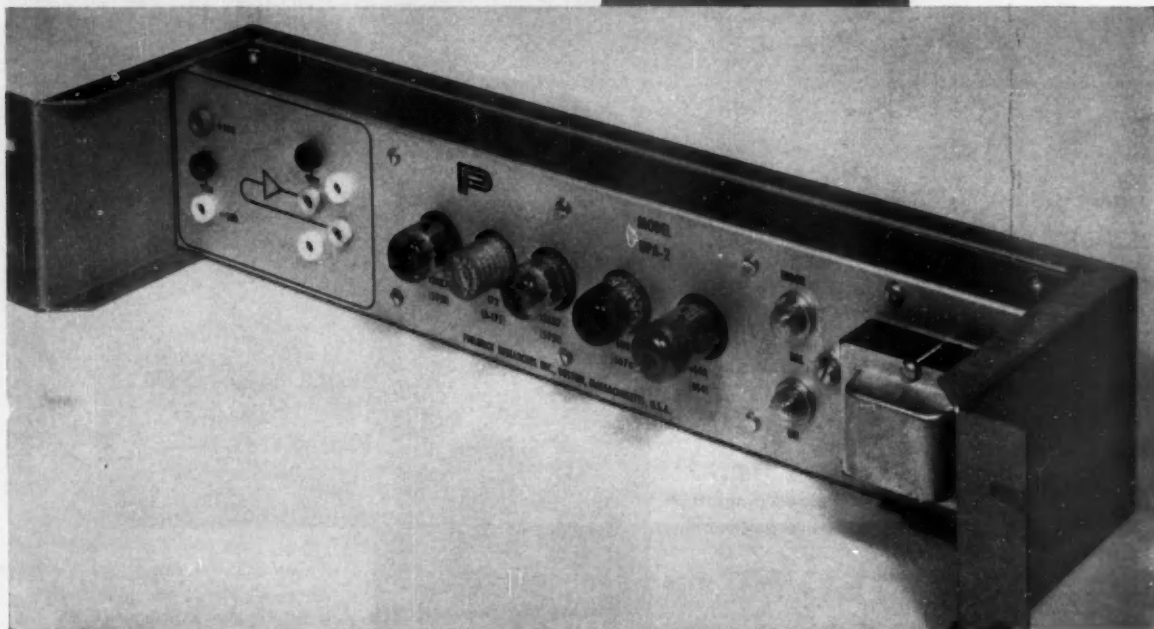
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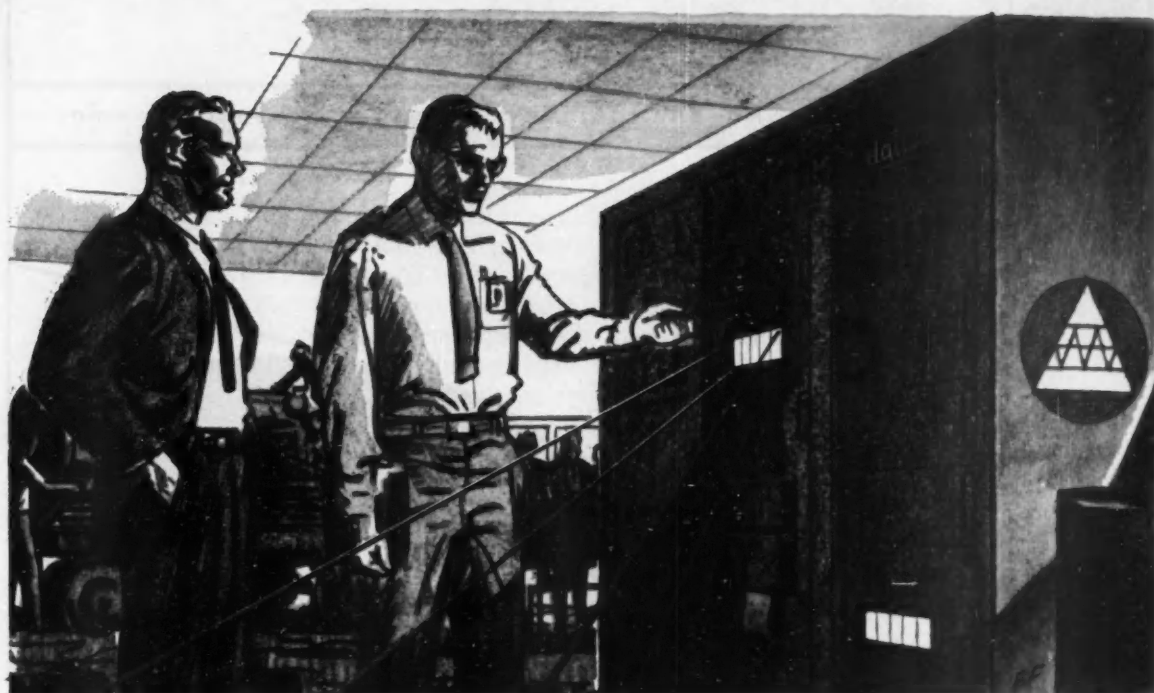
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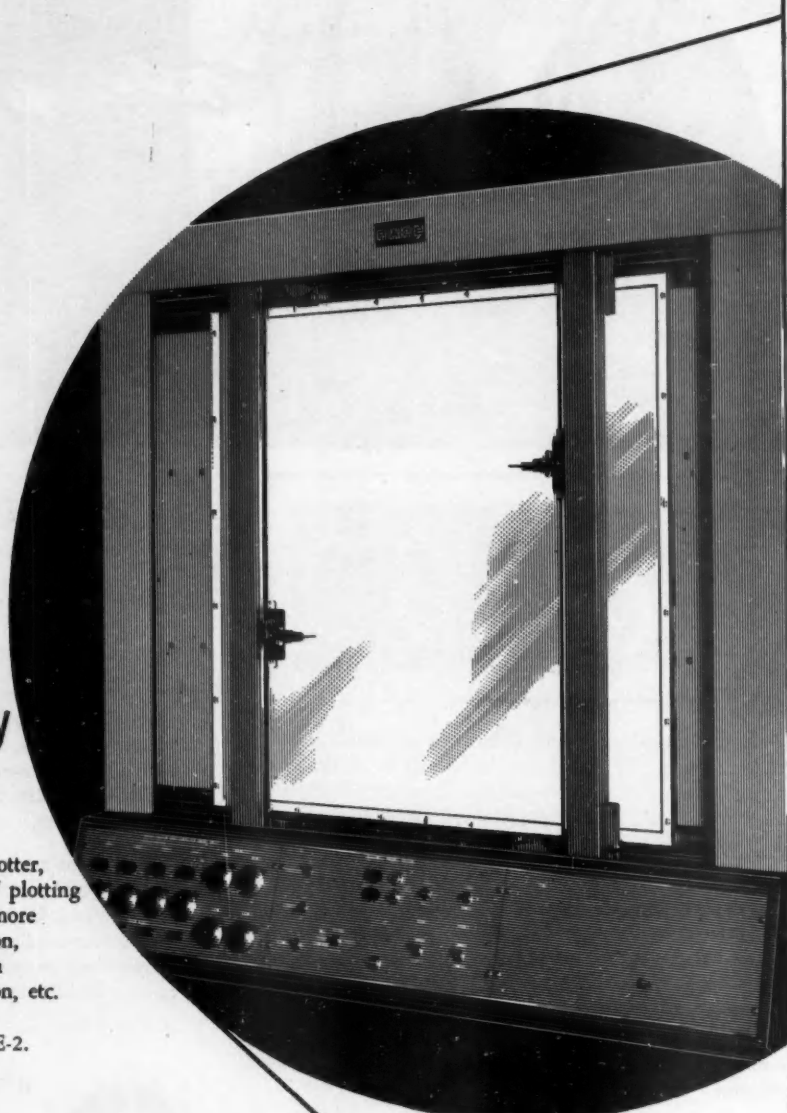
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115,000 New Users

Spreading out of traditional user industries, electronic controls are presenting some king-sized marketing problems to their makers. Frequently a lot stronger technically than business-wise, the manufacturers have run into a two-headed distribution problem: 1) how to provide application engineering for these new users, and 2) how to supply repair service and spare parts to them.

As recently as 1955, electronics original equipment manufacturers and the military market were by far the biggest users of electronic controls. Makers have done a good job of reaching these customers, primarily with a combination of their own sales force and manufacturers' representatives. But now three new markets exist and they promise to take a bigger and bigger share of electronic output. They are:

- Raw materials processing—chemical and petroleum products, rubber, paper, steel and other metals.
- Original equipment manufacturers—companies that are building electronic controls into the products they sell.
- Manufacturers who use electronically controlled equipment to build or test their products.

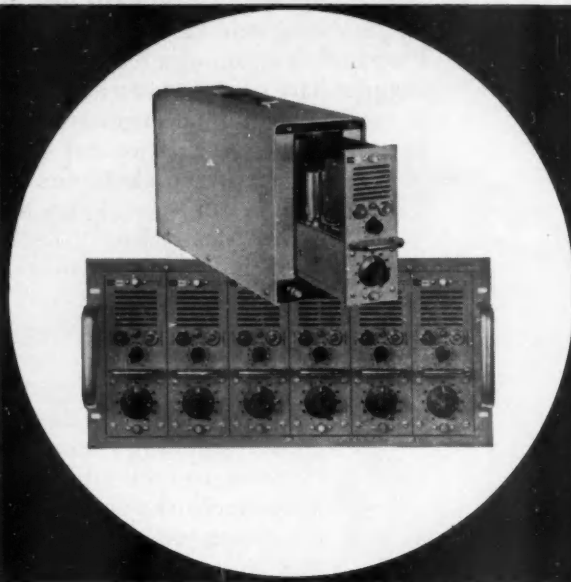
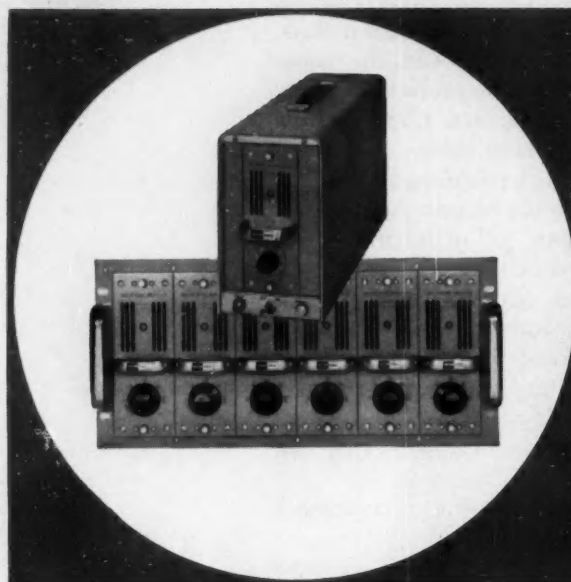
The big three

These new users are far more numerous than electronic companies. In 1958, *Electronics* magazine estimated that there were 3,600 makers of electronic equipment and components. Using the Department of Commerce's 1954 Census of Manufactures, CONTROL ENGINEERING estimates the establishments of the three new user groups total over 115,000:

Raw Materials Processing	Establishments	
Pulp and paper products	5,004	
Chemical products	11,075	
Petroleum and coal products.....	1,381	
Rubber	1,406	
Primary metal industries.....	5,838	
Stone, clay, glass.....	11,612	36,316
Original Equipment Manufacturing		
Machinery	25,601	
Electrical machinery	5,758	
Transportation equipment	5,348	
Instruments & related products.....	3,142	39,849
User Manufacturers		
Fabricated metal products.....	22,516	
Misc. manufacturing	17,010	39,526
Total		115,691

The sheer size of this potential market for control warrants a new look at marketing techniques. The problem is not the same for all control products. Control systems, for example, almost always require highly skilled engineers to provide application engi-

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neering, the most expensive kind of selling. But their relatively big price tag warrants the use of a company sales engineer or manufacturers' representative. Even so, most sellers of control systems have been content to "skim the cream", that is to contact only the biggest and most obvious potential customers.

When selling other control products—subsystems, instruments and test equipment, and components—the problem of reaching the 115,000 new potential users is even tougher. These devices require a less expensive method of distribution.

The electronics equipment industry previously sold some products to electronics manufacturers through electronic specialty houses or radio supply houses. Most of the new customers—used to buying from industrial distributors, including the electrical wholesaler, the chemical supply house, the mill supply house or the machinery distributor—are unfamiliar with them.

Are these other industrial distributors interested in selling electronic control products? The answer in practically every case is no! Even electrical wholesalers who sell many products akin to it are reluctant to take on electronic control.

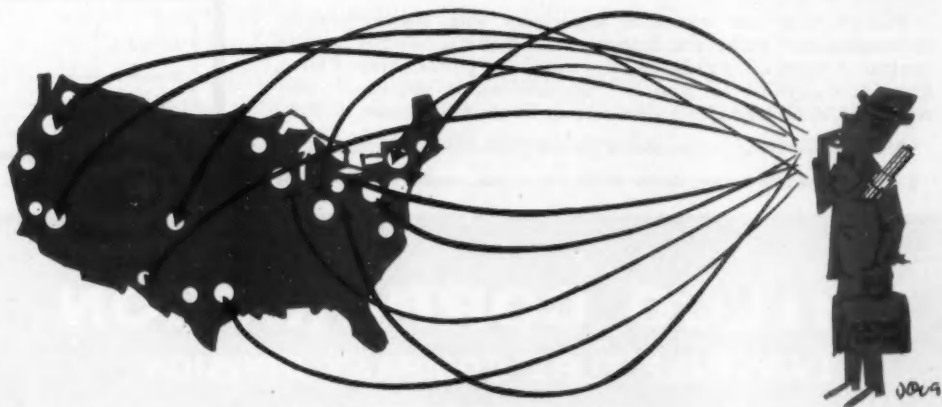
For one thing, the distributors feel that selling such equipment requires a level of skill well above what their average salesman has. For another, the inventory problem is too complicated—both physically and financially—for the average distributor. And distributors are much concerned with the problem of obsolescence. Electronic equipment design remains stable for many years. But electronic control components are frequently short-lived; new, improved versions arrive regularly.

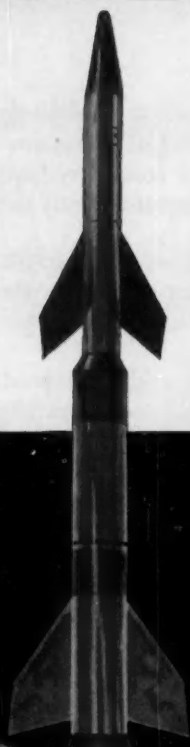
Apparently what's required to handle the job of selling electronic control products to the 115,000 potential users is some kind of cross between a manufacturer's representative with application know-how and an industrial distributor who will carry stock close to the user.

There's already been some stirring in this direction. A few electrical wholesalers have hired skilled engineers and are trying out selling electronic control. Many manufacturers' representatives have started carrying stock. In a recent survey, *Electronics* magazine quizzed a group of manufacturers' representatives, found that 50 percent of them had some warehouse or storage facilities. But the same study found that only 25 percent of the representatives were equipped to handle service calls on industrial equipment.

Unenthusiastic distributors

Something new needed





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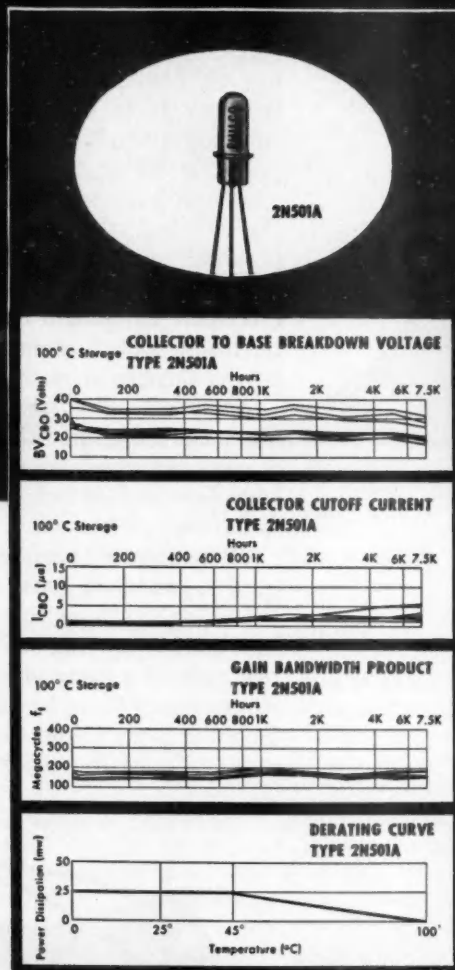
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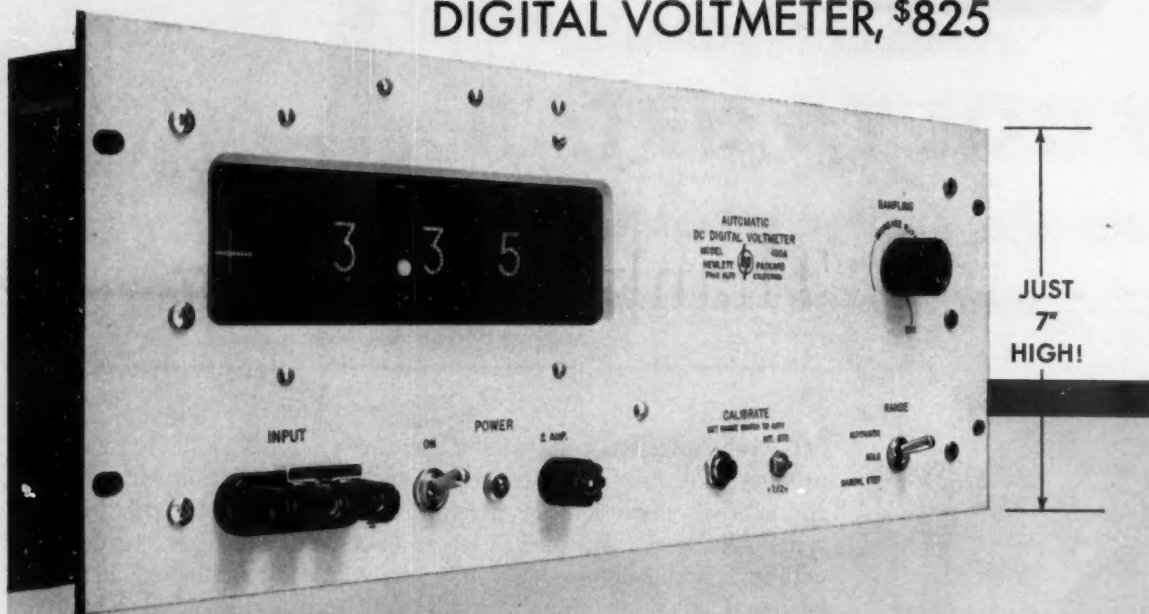
Give-and-take has come a long way in the control field. A few control product users still fear that revealing technical advances might endanger competitive production advantages. A few others have patented control systems for specific manufacturing processes. But overall, the tendency to withhold is dissolving slowly but surely. User and maker alike have become increasingly aware that release of technical knowledge catalyzes an exchange which makes it unnecessary for their engineers "to keep inventing the wheel".

Our author honorarium records offer impressive proof of how the exchange has spread throughout industry—and throughout the Western world. Manuscripts have come from England, France, Japan, Sweden, Denmark, Germany, and all corners of the U.S. A brief sampling of employers of U. S. authors demonstrates once more that the control field is a melting pot for industry, and that control products users and makers contribute important technological advances. Some typical employers: Boeing Airplane, Oilgear, Monsanto Chemical, Westinghouse, Jones & Lamson, General Precision Equipment, Rohm & Haas, U. S. Steel, Grumman Aircraft, General Electric, du Pont, Convair, Taylor Instrument, Phillips Petroleum, and Price Waterhouse. For publishing their know-how of techniques in instrumentation and control, authors and their employers have earned your thanks.

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Varistor Static Switching Networks for Multispeed Synchros

Multispeed synchros used for position measurement require some form of switching to allow each synchro in its proper turn to take over the feedback function. The demand for reliability in numerical positioning systems has led to the investigation of a new basic concept in static switching networks. Key element in the development is the Thyrite varistor, which functions as a non-linear voltage divider in the logical networks of the control.

L. U. C. KELLING
General Electric Co., Waynesboro, Va.

For some time, multispeed synchro arrangements have provided a convenient means for electrically measuring linear and angular displacements. One decided advantage of this method is that it allows the control engineer wide latitude in the choice of the level of measurement accuracy. The degree of precision attainable is proportional to the number of synchros employed, and combinations of from two to five and more units are common. The five-synchro system, for example, has given excellent results in numerically controlled machine elements such as the punch-press positioning table in Figure 1. In this application, the synchros are geared together so that successive units rotate once for each 1,000,000, 100,000, 10,000, 1,000 and 0.100 in. of linear travel.

Switching is an important function within all multispeed synchro systems because the chain of command must be passed successively from the coarse to the fine-accuracy units as the machine progresses toward correspondence with the instructed dimension. In two-speed systems, this switching has been accomplished successfully by relay and neon lamp takeover (switching) circuits. These circuits, however, proved too costly and complex for higher-order, multispeed synchro arrays. The resulting search for a more suitable switching means led to the development of takeover networks employing Thyrite* varistors. The varistor takeover circuits are simple and passive. The latter characteristic

* Registered trademark of General Electric Co.

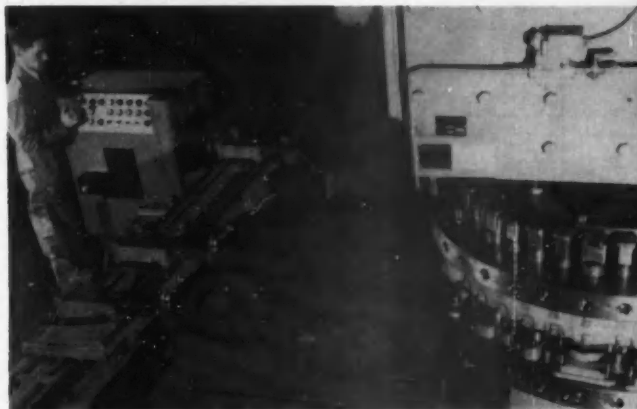


FIG. 1. Numerically controlled punch press with multispeed synchro position-measuring system.

gives them the distinct advantage of great reliability.

The varistor takeover circuit is in essence a nonlinear voltage divider. The nonlinear element is the varistor, whose resistance varies inversely with applied voltage. This characteristic makes it possible for the voltage divider to serve as a voltage-sensitive switch.

Thyrite varistors are made of silicon carbide in the form of rods and discs in a wide variety of nonlinear resistance ranges. The varistor (GE Catalog No. 8386118G2) chosen for this application has a working voltage of from 2 to 35 volts and good nonlinear performance and is free of polarity effects. It fits well into a nonlinear voltage divider circuit for operation on the peak voltages of 81 volts obtained from synchro control transformers. The character-

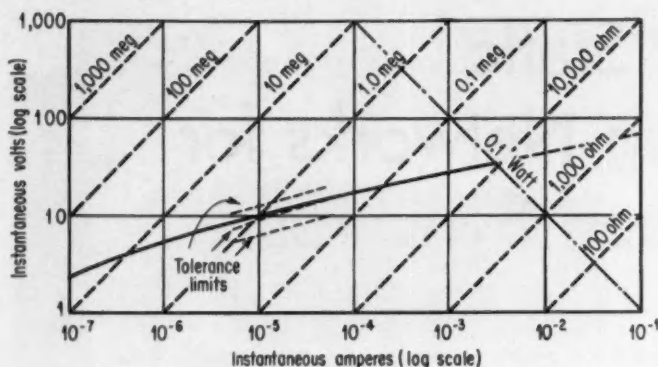


FIG. 2. Characteristic curve of Thyrite varistor showing change of resistance with respect to voltage. Dashed lines are voltage-current relationships for conventional linear resistors of various values.

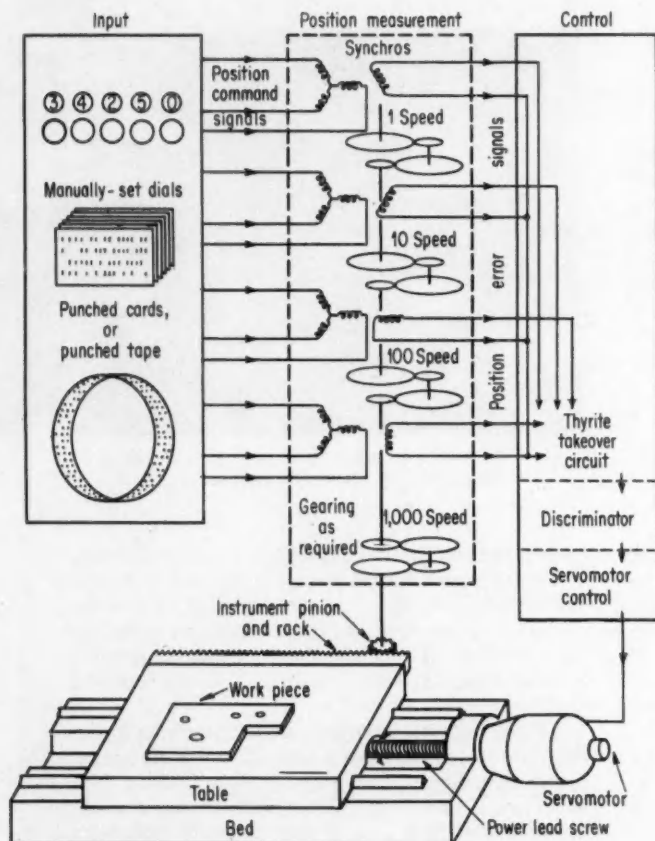


FIG. 3. Schematic of multispeed synchro numerical positioning control for a machine tool worktable.

istics and tolerance limits of this varistor are shown in Figure 2. This unit is a disc measuring $\frac{1}{2}$ in. in diameter and 0.080 in. in thickness. It has wire leads.

Circuit operation

The functioning of the varistor take-over circuit is best explained with reference to its place in a typical system. Figure 3 is a schematic diagram of a multispeed synchro system for machine tool positioning. The director reads punched card or tape data and produces position command signals for each of the synchros of the position-pickup unit. The ac command signals are applied as excitation to the stator windings of each of the synchro control transformers of the position-feedback unit. Each set of excitation voltages produces a pulsating, single-phase flux that induces an error signal in the corresponding rotor winding. The magnitude of each error voltage is a function of the angular displacement of the rotor from its zero error position. A control transformer is in correspondence with the director signal when the output voltage is zero and has a specific phase relationship to the ac reference voltage for small deviations from zero in a specified direction.

With large errors between the director output and the position-pickup unit, only the electrical signals from the low-speed synchro will be in the proper direction to drive the machine slide toward correspondence with the instructions. The signals from the other synchros will at times be in the wrong direction. When the slide has moved to a position where the error signal of the low-speed synchro is small, the next lowest-speed synchro takes over, until its error signal, too, reaches a low level. In this way, the command is successively passed down to the high-speed unit. This "passing down" or switching process is the function of the takeover circuits, which connect the output of each synchro transformer in its proper turn to the control.

Figure 4 shows the takeover circuits,* which are applicable to two-, three-, four-, and five-speed combinations. In the four- and five-speed systems, there is some loss of accuracy with respect to the high-speed signal. For this reason, it may be preferable to use one of these

* U. S. Patent No. 2,764,720.

circuits for coarse synchronizing, followed by a relay stage for switching to the signal of the highest-speed synchro or to a mixed signal of the two highest-speed synchros.

Circuit structure

The four-speed takeover network of Figure 4C comprises a summing circuit (points C, F, J, L), a group of comparing circuits (points B-C-D, D-E-G and G-H-K), and a group of injection circuits (points E-F, H-I, and K-L). The comparing circuits are nonlinear voltage dividers connected between the outputs of successive parts of synchro output signals. Each divider consists of a fixed resistor and a nonlinear varistor in series, which share the total voltage across the divider as a function of that voltage. For low total voltages, the smaller portion of the voltage drop is across the fixed resistor. For large total voltages, the smaller drop is across the varistor. Thus, the voltage of the tap point moves from close to the resistor input at low total voltages to close to the varistor input at high voltages.

The voltage signals at points E, H, and K are injected into the summing circuit through the Thyrite varistor injection circuits whenever there is an appreciable voltage difference across the injection circuits. The output signals of all but the highest-speed synchro are introduced into the summing circuit by two paths, each of which compares the signal with that of the adjacent synchro. This procedure insures that even small signals from the lower-speed synchros will be able to overpower any signals from the higher-speed synchros.

A method was developed to control the limit values of resistance of the nonlinear elements at critical locations within the circuit. Figure 5 indicates how the minimum value of resistance can be controlled by the addition of a series-limiting resistor, and how the maximum value of resistance can be controlled by the addition of a parallel-limiting resistor. Series and parallel resistors can be added simultaneously to limit both maximum and minimum values. This technique reduces the effect of tolerance variations in the nonlinear elements on the output voltages of the circuit.

Because there is a rather steep change in voltage at the 0 and 180 deg points of the sine wave, little error is introduced into design reasoning by assuming that the input voltages to these circuits are

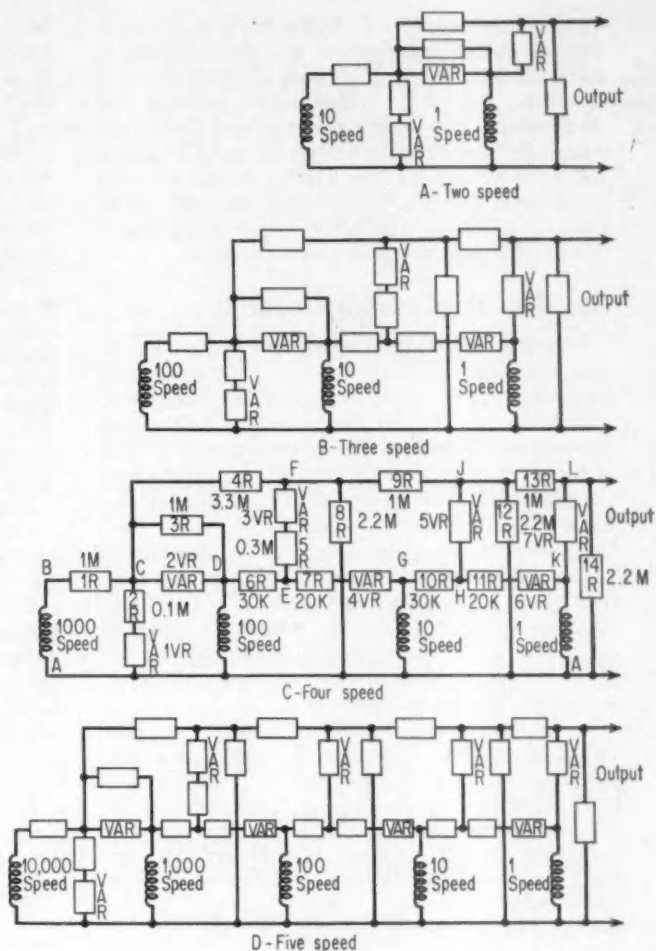


FIG. 4. Typical Thyrite varistor takeover circuits for positioning measuring systems employing two to five synchros.

square-wave voltages of magnitude equal to the rms magnitude of the sine wave. A rigorous mathematical solution of these nonlinear circuits is impossible, but rough solutions for small portions can be easily made on this basis.

From the circuits sketched in Figure 4, it will be noted that the low-speed units are connected nearest to the output of each varistor takeover circuit. Generally, the synchro control transformers have a maximum output voltage at 90 deg from correspondence of 57 volts rms or 81 peak volts. This is equivalent to 1 volt rms per degree of error near correspondence. A comparison of the varistor characteristics with the values of the fixed resistors given on this diagram indicates that the Thyrite resistances vary both above and below those of the fixed resistors, depending upon the voltage magnitudes. Thus, each varistor at certain times increases the magnitude of output

signal voltage and, at other times, limits it. Since the synchro control transformers are producing an ac voltage output, the varistors have different effects at different points on the voltage wave. However, the main concern is when the magnitude of the voltage is large and near or above the rms value. The output voltage waveform of the Thyrite takeover circuit has some distortion, but it is not excessive. This leads to reasonably consistent action at all magnitudes and combinations of synchro voltages.

Operation at various displacements

At very small position errors and low error voltages, the resistance of all varistors is higher than 10 megohms. Under these conditions, it is possible to assume that the Thyrite resistances are infinite and the output voltage is a function only of the value of the fixed resistors of the circuit. Figure 6 shows that for small errors in correspondence, the ac voltage of the 1,000-speed synchro will be larger than the voltage of any of the others. Thus, the output will be primarily a function of the signal obtained from this highest-speed synchro. As the error increases, the ac signal voltage output of the 1,000-speed synchro increases rapidly while the voltages of the 100-speed, 10-speed and 1-speed units increase at progressively slower rates.

In the region of 20 to 160 deg displacement, the voltage at point B of Figure 4C is large, and the resistances of varistors 1VR and 2VR decrease to limit the rise of voltage at point C. Further, since the voltages at points F, J, and L are somewhat larger than the voltages at points E, H, and K respectively, varistors 3VR, 5VR, and 7VR have a slight further effect in limiting the output voltage. In this region, resistor 2R and varistor 1VR function to limit the voltage at point C. This prevents the output voltage from being higher in the 20 to 160 deg range than it will be around and beyond 180 deg, where the voltage at point B opposes the voltage at point D. The output voltage of the Thyrite

takeover circuit must then continue to rise with increasing displacement through the region where the signals of the 1,000-speed synchro first oppose those of the 100-speed unit (when the latter's signal is of only moderate strength).

When the high-speed synchro is between 180 and 360 deg from correspondence, the output signal of the Thyrite takeover circuit continues to rise smoothly with increasing displacement. The non-linear voltage divider between the two highest speed synchros keeps the potential at point C close to that of point D, thereby limiting the effect of the 1,000-speed signal. Meanwhile the voltage at point D is not too large with respect to point G, and point E remains close to point D. The signal of the 100-speed synchro is thus injected through resistor 5R and varistor 3VR into the summing circuit, overcoming the opposing polarity signals of the 1,000-speed synchro in this region.

Between 360 and 1,620 deg displacement, the output signal voltage of the 100-speed synchro is quite large and injects such strong signals into the summing circuit that any signals from the 1,000-speed synchro have but little effect on the output. The output of the takeover circuit continues to rise to somewhere beyond 900 deg total displacement (90 deg for the 100-speed synchro), then falls slightly as the 100-speed synchro approaches 1,620 deg and its output drops. Within this region the output signal of the 10-speed synchro begins to acquire some magnitude.

Within the band from 1,620 to 1,800 deg the signals of the 100-speed and 10-speed synchros have the correct polarity but are limited in magnitude. At the same time, the signal of the 1,000-speed synchro is large and opposes the correct signal polarity. In this region, the signals of the 10-speed synchro insure that the correct polarity of the output signal of the takeover circuit is maintained and that signal strength does not dip excessively.

From 1,800 to 1,980 deg, the signal of the 100-speed synchro increases in magnitude, but is of the wrong polarity. Here, the comparing circuit between points D and G shifts the potential of tap point E closer to that of point G and limits the magnitude of the opposing polarity signal introduced to point F through the injection circuit. Thus, the increasing signal from the 10-speed synchro can overcome opposing signals and increase the magnitude of the takeover circuit output signal in the proper direction. This occurs even though the signals of both higher speed synchros oppose that of the 10-speed synchro.

Beyond 1,980 deg, the output signal of the takeover circuit continues to rise with some minor fluctuations as the polarity of the output signals of the

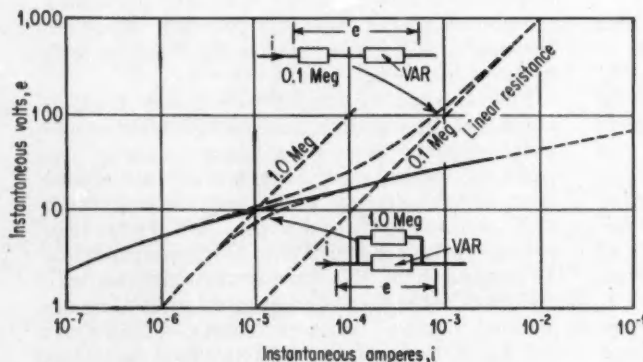


FIG. 5. Curves showing effects of adding linear resistors in series and parallel as means for limiting varistor resistance range.

1,000-speed and 100-speed synchros change. When the magnitude of the 10-speed synchro signal falls beyond 16,200 deg, control is again transferred, this time between the 10-speed and the 1-speed synchros and in the same manner as described for the change of command between the 100-speed and the 10-speed synchros. At this transfer, there is a dip in the output signal to a minimum somewhat higher than in the 1,620 to 1,980 deg region.

Between 18,000 and 90,000 deg, the output signal continues to rise with displacement with some minor variations due to reversals of signals of the three highest-speed synchros. The signal gets larger after each transfer of command to a lower-speed synchro. From 90,000 to 162,000 deg, the signal falls gradually, though it remains quite large in comparison to the signal magnitudes during the first 360 deg of displacement. Slightly beyond 162,000 deg, the 10-speed, 100-speed, and the 1,000-speed synchros (singly or in combination) produce signals that are of the wrong polarity and of sufficient amplitude to reverse the polarity of the output signal. In the regions beyond plus or minus 162,000 deg total displacement of the 1,000-speed synchro (162 deg displacement of the 1-speed synchro), the output signals are not usable because they are apt to change polarity many times. This limits the range of usefulness of the Thyrite takeover circuit to plus or minus 162 deg of rotation of the lowest-speed synchro for 10:1 gearing ratios.

Circuit characteristics

There is a tendency for the output signal of the takeover circuit to dip at each point where the command is passed from one synchro to the next. At these points, the higher-speed synchro signals have maximum effect in opposing the next lower-speed synchro signals. This condition occurs at approximately 180, 1,800, and 18,000 deg in the four synchro systems described. The tendency to dip is somewhat greater for even synchro gear ratios than for odd ratios and, in addition, increases with the magnitude of the gear ratio. The takeover circuits in Figure 4 are designed to suppress dip conditions at the takeover point between the two highest-speed synchros. The circuit connecting the two highest-speed synchros differs from that used between the mid- and lower-speed pairs. And, servo gains can be set so that the motor reaches full speed for signal magnitudes below that of the lowest dips.

Measuring systems employing even gear ratios run into difficulty at about 180-deg displacement of the lower-speed synchro because in this region the output voltage envelopes of the two adjacent synchros have opposite polarities. Obviously, this difficulty

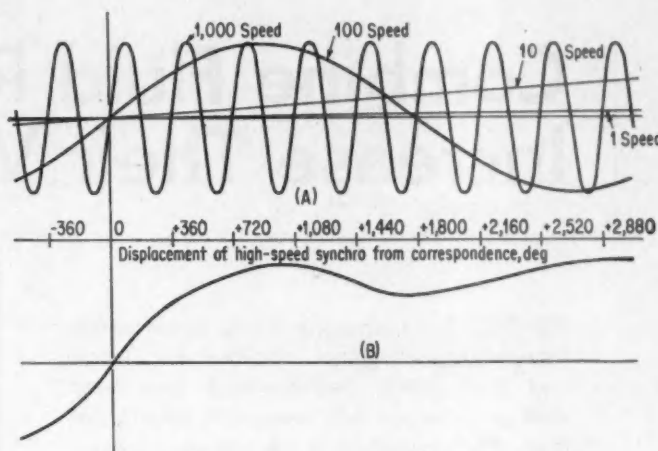


FIG. 6. Curves of input and output signals for varistor takeover circuit. Curves A represent synchro signals and Curve B is the output voltage of the takeover.

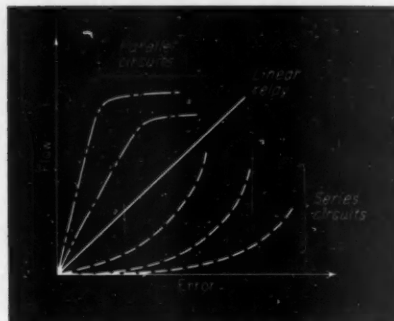
is not experienced with odd gear ratios. Because decimal gearing is frequently chosen to match decimal input instructions, this problem is a real one, often limiting the maximum travel in any one positioning step to plus or minus 162 deg of rotation of the lowest-speed synchro. Circuits having the component values shown in Figure 4 are limited to maximum synchro ratios of 10:1 to possibly 13:1. Above that, the dips in output voltage at the takeover points would cause drops in motor speed and possible loss of sense of direction. The two-speed takeover circuit is effective at gear ratios of up to 36:1, although there is a considerable dip at 180 deg.

The output signal of the takeover circuit has a voltage that varies in magnitude as a function of displacement of the high-speed synchro, Figure 6. The signal rises until approximately 900 deg, dips a little around 1,800 deg. In addition, it rises and dips at successively higher magnitudes for the 90- and 180-deg regions of the lower-speed synchros. Signal amplitude will drop ultimately when the low-speed synchro signal decreases and is opposed by the signal of the next-higher-speed synchro. Although there is some distortion in the output voltage, it does not interfere with proper action of the discriminator circuit. The voltages obtained from the circuits in Figure 4 are 20, 8, 2.5, and 1 rms volts, respectively, at 360 deg displacement of the high-speed synchro. Varistor capacitance causes a small phase shift of the higher-speed synchro signals at 400 cycles. This shift is negligible at 60 cycles, however.

For higher-order, multi-speed Thyrite takeover circuits, there is some noise and, hence, loss of accuracy in the output signal. For greater accuracy, therefore, it may be advisable to use two different Thyrite takeover circuits with a relay switching between them at errors of a few hundred degrees. The first circuit would span all but the high-speed synchro, the second, the two highest-speed synchros.

Combine Fluid Relays to Increase Their Versatility

THE GIST: Fluid relay signal and power amplifiers—with mechanical displacement inputs and fluid power outputs—have long been used in hydraulic and pneumatic control systems. The oldest type is the four-way valve—originally developed to control steam power—while the double-restriction relay and the jet pipe are relative “newcomers”. All three are finding increasing use in military and industrial applications.



Most engineers consider the ideal relay one that has a linear gain characteristic of flow or pressure vs. error or displacement; this is typical of the basic push-pull circuits of the three relay types. Quite often these basic types can be combined to achieve special characteristics, such as low noise level, increased capacity without lower performance, or nonlinear gain. In the accompanying sketch the nonlinear curves below the linear relay characteristic result from combining relays in series, from adding restrictions with nonlinear flow characteristics, or from using multiple-speed boosters; those above the characteristic, from paralleling relays and from using boosters and restrictions that are more effective at higher flow rates. After reviewing the basic valve types, Author Ziebolz points out seven specific characteristics that can be achieved by combination and modification of these three basic valve types. He concludes that with sufficient ingenuity the control engineer can obtain any gain characteristic he desires in the quadrant bordered by the flow and error axes.

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Power amplifiers with force or displacement inputs and fluid power outputs are finding increasing use. The big three in this class are the four-way or spool valve, the double-restriction relay, and the jet pipe. The following compares their characteristics, defines their common denominator, analyzes their limitations, and explores the possibility of extending their usefulness.

The four-way valve

The basic four-way valve consists of a spool arrangement, Figure 1A, whose displacement relative

to one or two ports controls the direction and amount of energy applied to the load. The relationship between spool displacement and flow is substantially linear, Figure 1B. The flow Q is based on a no-load condition and, for a given valve, varies with pipe resistance, difference in elevation, supply pressure, and other load factors. The change in flow as a function of stalling load (maximum differential pressure times effective piston area) is given in Figure 1C. The individual relay characteristics—dead zone and gain—depend on the physical dimensions and the relative geometry of ports a and b and lands c and d shown in Figure 1A.

Various attempts have been made to reduce the manufacturing difficulties of controlling the desired

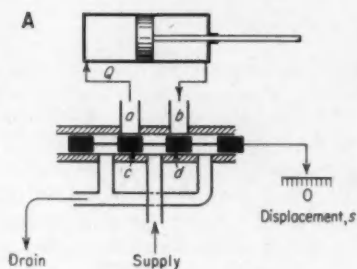
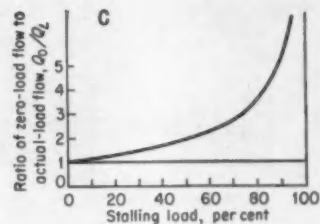
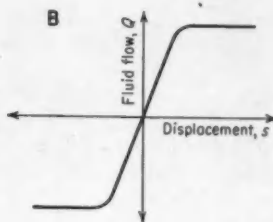


FIG. 1. A—Basic spool-type four-way valve.
B—Relationship between flow and spool displacement is essentially linear.
C—Change in flow as a function of stalling load.



THE FOUR-WAY VALVE

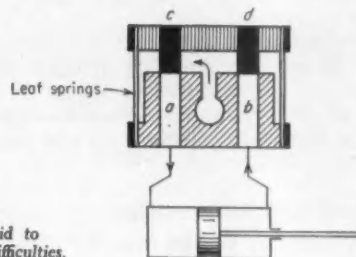


FIG. 2. Plate-type four-way valve is said to reduce machining difficulties.

THE DOUBLE-RESTRICTION RELAY

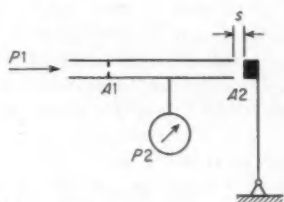


FIG. 3. One restriction is fixed, the other variable.

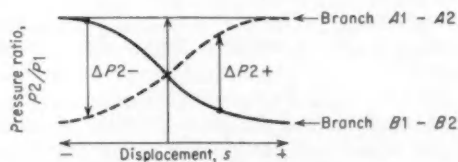
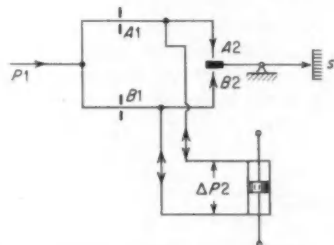


FIG. 6. Push-pull double-restriction relay and its characteristic curves.

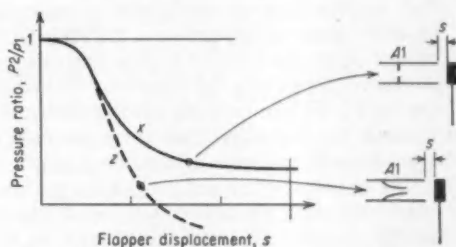


FIG. 4. Using an injector nozzle (curve *z*) instead of an orifice restriction (curve *x*) increases output range and improves linearity and gain.

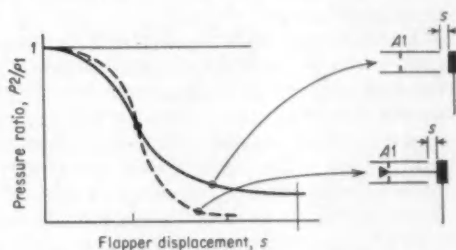


FIG. 5. Similar results to those shown in Figure 4 can be achieved by varying both restrictions.

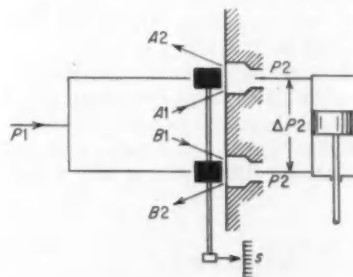


FIG. 7. Small lands and large ports make a double-restriction relay out of the four-way valve of Figure 1A.

THE JET PIPE

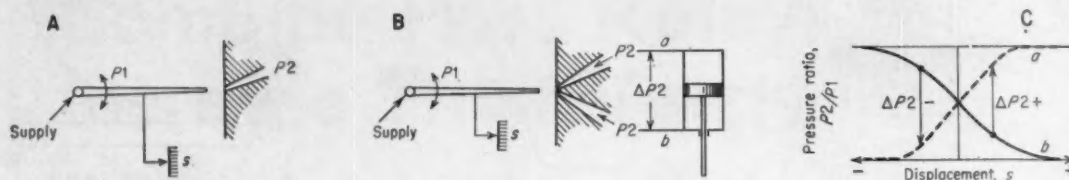


FIG. 8. A—Basic jet pipe. B—Push-pull jet pipe relay. C—Performance curves of push-pull jet.

match between the spools and the ports, the most radical one being the sandwich arrangement of circular ports and plugs shown in Figure 2. Here the perfect fit of plugs *c* and *d* and ports *a* and *b* is automatically obtained by drilling the two pieces simultaneously.

The double-restriction relay

If the lands are smaller than the ports, the four-way valve becomes a specific type of push-pull double-restriction relay. The basic double orifice relay—used in thousands of pneumatic amplifiers—consists of a supply tube with a fixed restriction (*A1* in Figure 3) in series with a variable restriction *A2*. The intermediate or modulated pressure *P2* is a function of the supply pressure, the ratio *A1/A2*, the ratio of *A1* to the conduit or pipe area, and the fluid constants. By varying the flapper or throttle displacement *s*, *P2/P1* can be modulated as shown in Figure 4, curve *x*. Note that this curve is nonlinear and approaches a minimum greater than zero.

If it is necessary to reduce the output to zero or below, the first restriction can be changed to an injector nozzle. The result is shown in Figure 4, curve *z*. This not only increases the usable output range, but improves system linearity and gain. By simultaneously varying *A1* and *A2*, the same result of increased gain and reduction to zero output can be obtained, Figure 5.

The push-pull circuit of Figure 6 makes this type relay usable with double-acting cylinders. Applying the push-pull or fluid-bridge double-throttle principle to the four-way valve yields the circuit shown in Figure 7. This is similar to Figure 1A except that lands *c* and *d* are smaller than the corresponding ports *a* and *b*. This circuit is widely used where the constant leakage at zero displacement is not objec-

tionable, and where the sharp zero characteristic of the push-pull circuit is essential.

The jet pipe

The fluid jet pipe relay produces a modulated output pressure or pressure differential by displacing a high velocity jet relative to a receiving orifice, Figure 8A. Figure 8B shows the same relay in a push-pull circuit, while Figure 8C shows the individual output characteristics *a* and *b*. The *P2/P1* curves are rather linear, not only in ΔP , (as shown), but also in output flow *Q* (not shown). Note that both curves *a* and *b* go to zero.

In the conventional jet pipe, the supply nozzle moves and the receiving orifice is stationary. However, in some applications, it is more convenient to have the orifice move and the supply nozzle stand still. Other useful configurations of the jet pipe relay have also been developed (see Ref. 1).

About 90 percent of the supply pressure is the maximum that can be regained in the receiving orifice, and about the same amount is transmitted as maximum flow through a suitably matched orifice. Typical hydraulic relays use pressures ranging from 100 to 200 psi. The maximum jet nozzle diameter used so far is about $\frac{1}{8}$ in., unless the nozzle of a Pelton wheel is considered to be a relay.

If it is, incidentally, the jet energy is controlled by throttling the supply or by intercepting the jet with a deflection mechanism. A small version of the same technique has been successfully used in a modified jet relay system, where an interceptor blade modulates the flow to the receiving orifice.

This completes the review of relay types and their characteristics. The remainder of this article will show how to combine the valve types to obtain specific useful characteristics.

1. Combining Low Noise Level With High Capacity

From the viewpoint of input force level versus energy output, the four-way valve is least satisfactory. Not only is the spool static friction so high that it has to be reduced in critical cases by continuously rotating the sleeve, but it has also been found that the fluid flow through the valve creates dynamic unbalances that mask the signal. Considerable work has been devoted to reducing this dynamic effect, and

to a remarkable degree this effort has been successful.

The two-orifice or flapper valve has a far better signal-to-noise ratio, particularly in the relatively low range of 3 to 15 psi, where this type relay is used in great numbers. The fundamental drawback is that the fluid usually acts in the same direction, opposing the input signal and introducing a dynamic force and hence an error. This error can be reduced by a

flapper or vane arrangement that produces a throttling action perpendicular to the fluid flow, but it cannot be completely avoided.

In the jet relay, the fluid forces react through the fulcrum of the jet pipe. However, the jet pipe, like the double-orifice throttle valve, is limited in the maximum energy that can be handled by one nozzle. In general, this maximum is below 1 hp.

A logical approach, then, is to combine the low noise of the double-orifice or jet relay with the high capacity of the four-way valve. Figures 9A and 9B show two ways to do this. The follow up in Figure 9A is accomplished by a fluid resistance push-pull circuit of the type shown in Figure 7. A displacement s unbalances the bridge (changes the ratio of the outlet areas A_2/B_2) and produces a pressure differential that forces piston C to follow the displacement as if mechanically connected. This motion is accomplished by pressure unbalance of the bridge, which provides sufficient power gain to overcome the friction

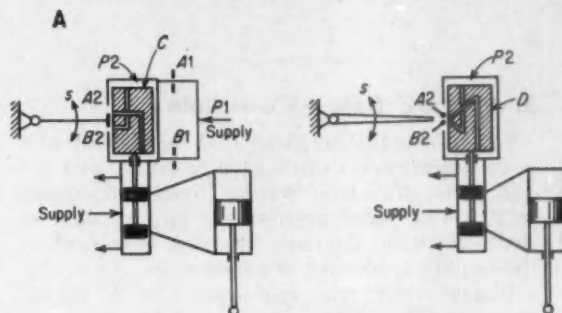


FIG. 9. Combining the four-way valve with the double-restriction relay, A, or with the jet pipe relay, B, gives high capacity and low noise.

tion of the four-way spool. The friction force is not reflected back to the input.

The same basic idea is incorporated in the jet-relay/four-way-valve assembly of Figure 9B. The follow-up piston D carries with it the two receiving orifices of the basic push-pull circuit (shown in Figure 8B), thus coupling the valve to the relay.

2. Paralleling Relays to Increase Volumetric Capacity

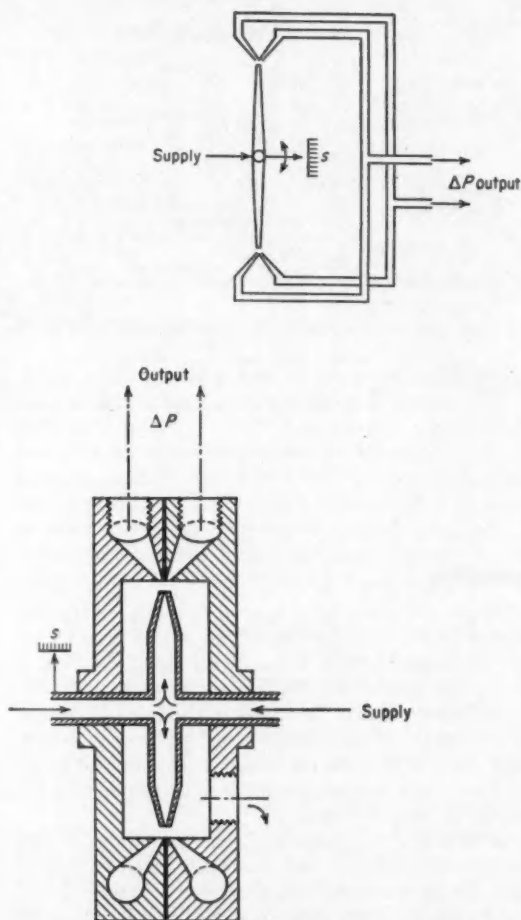


FIG. 11. In the extreme case of paralleling, the individual jets form a continuous sheet of fluid.

FIG. 10. Paralleling relays increases capacity.

Since cylinder speed for maximum error signal is a function of relay capacity, cylinder volume, supply pressure, and load, there is a maximum rate of load travel for a given control circuit. The ability of the control to correct for transient disturbances depends primarily on the volumetric capacity of the relay system, and in most cases, since supply pressure cannot be changed, other means must be found for speeding up the cylinders or valve operators.

An obvious approach is to increase capacity by increasing the dimensions of the relay. However, increased nozzle diameters reduce the pressure gain—unless the relay lever arm ratios are simultaneously maintained. But here too, there are limits, since an increase in physical dimensions usually increases noise, torques, and system inertia.

All this can be avoided simply by a multiple-relay system such as the one shown in Figure 10. In the extreme case, this approach produces a relay in which the individual jets form a continuous sheet of fluid, Figure 11.

Note that the jet relay uses fluid at a constant rate regardless of load and therefore differs from the double-throttle design, in which fluid demand varies with displacement. In some cases this constant fluid load is an advantage: it simplifies the supply pressure control problem. Relief valves have limited turndown ranges and stability (chatter) problems of their own.

3. Varying Relay Flow Gain

Closed-loop analysis shows that the stability of a given system depends to a large extent on amplifier gain. Gain (the ratio between input and output, be it flow or pressure) is usually easy to adjust in electrical systems, but more difficult in systems where the amplifying element is a fluid relay.

In a given fluid relay, gain depends on the geometry of the equipment, energy demand, line resistance, and supply pressure. Changing the supply pressure appears to be the ideal way to get proportional gain variations, but this is usually impractical for one of two reasons: either pump pressure is limited, or load requirements will not permit pressure reductions. As a result, it is normally necessary to vary the line resistance. Figures 12A to 12C show three relay circuits with throttle valves *a* between the cylinders and the relay output connections, while Figure 12D gives the resultant characteristic curves.

Assuming that all three relays have a linear flow vs. error characteristic with valve *a* wide open, the basic gain of the system is given by the constant slope of its characteristic curve. Inserting a throttle valve with quadratic resistance to flow makes the gain very nonlinear, i.e., very effective at large errors and less so for small ones (see needle valve curve). A linear reduction of gain can be achieved if a capillary is used and flow is restricted to the laminar range (see capillary curve). However, capillary tubes or their equivalents clog easily and are usually highly sensitive to temperature variations.

In addition, reduced maximum speed may be objectionable in emergencies (or during manual startup), so that it is often desirable to produce the mirror image of the needle valve curve: low gain at small errors and high gain at large errors.

Several ways have been developed to obtain linear or nonlinear valve gain characteristics. The most convenient way to linearly reduce gain is by means of a variable outlet port in a booster-relay combination. The design in Figure 13 accomplishes this by combining an undercut pilot valve spool with an adjustment of this spool relative to the outlet ports in the booster sleeve.

4. Obtaining Nonlinear Flow Gain Characteristics

In many applications (a proportional speed floating controller is one) it is necessary to reduce the gain to maintain stability. Usually, however, this reduction in speed conflicts with the requirement of higher operating speed to match process transients or to meet specifications for emergencies or manual starting. For this reason it is often desirable to have a relay with a gain characteristic that varies from low to high as error increases. In the extreme case, such a system is represented by a relay with a center dead zone and full speed in either direction.

Figure 14 shows a fluid relay system in which the desired nonlinear gain characteristic has been

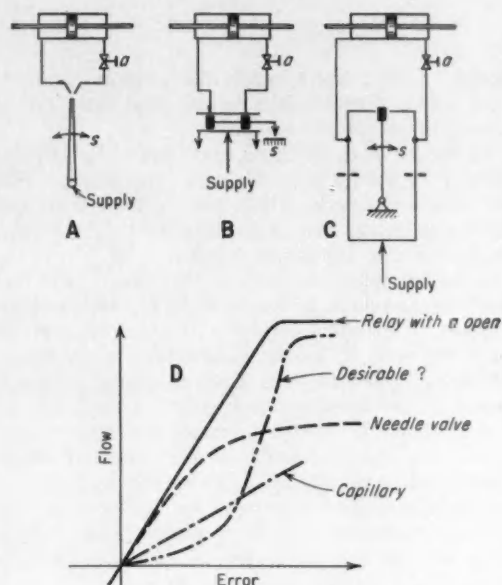


FIG. 12. D shows how flow gain varies by changing characteristics of throttling valves *a* in A, B, and C.

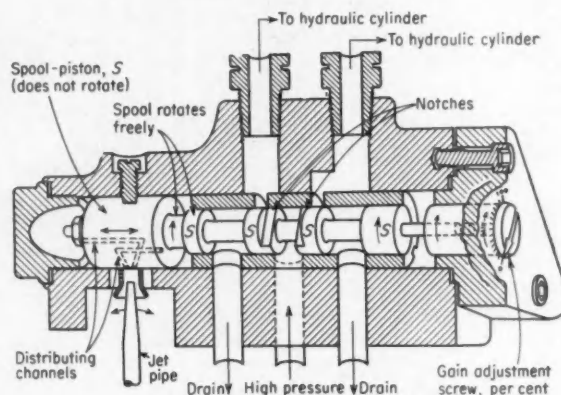


FIG. 13. Adjusting angular position of undercut spool linearly reduces flow gain.

achieved by inserting a special variable restriction in one of the cylinder lines. The device consists of two preloaded check valves with needle valves *a* and *b* that operate in the laminar flow range. With a small error signal the fluid is throttled by these valves which, if completely shut, produce a center dead zone. When the error reaches the preload level, the check valves open, permitting corresponding increases in output speed.

With this arrangement high emergency speeds and low gain around zero error are both possible, Figure 14B. So are asymmetrical characteristics with a different gain in either direction—by suitably adjusting

the needle valves *a* and *b* and the spring preloading.

In the design shown in Figure 15A, nonlinearity adjustment is obtained by combining the adjustable port booster of Figure 13 with a spool-type check valve arrangement. The left-hand adjustable booster is the type previously discussed, follow-up piston *a* following jet relay displacement *s*, except that the displacement is limited by stops *S1* and *S2*. As these limits are reached, the movable receiving orifices become stationary and the respective pressures in lines *b* and *c* are applied to the spring-biased four-way valve *d*. The result is a proportional spool displacement. Figure 15B shows the characteristics.

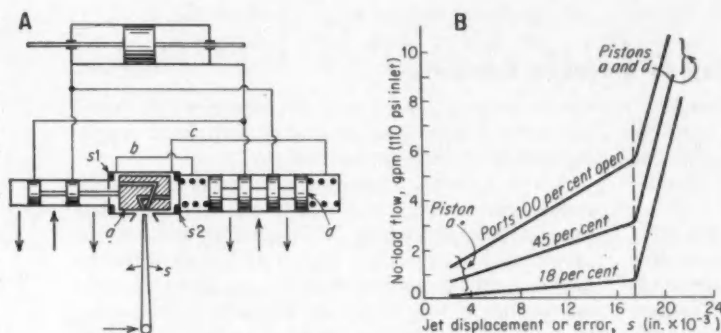


FIG. 15. A shows a special relay arrangement to achieve the nonlinear gain characteristics in B.

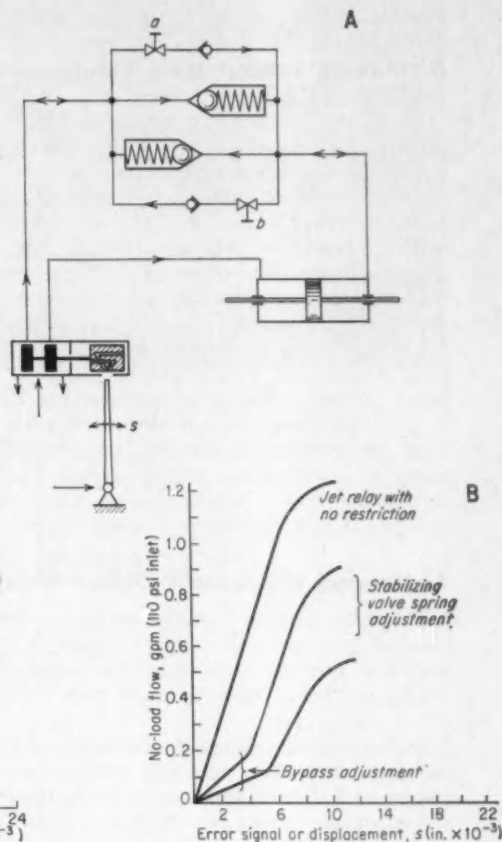


FIG. 14. By changing the check valve springs and adjusting the throttling valves *a* and *b* in the circuit of A, various nonlinear gain characteristic curves can be achieved, as shown in B.

5. Combining Linear Relays in Series to Obtain Nonlinear Gain

The technique discussed above is particularly useful for obtaining the required gain characteristics without changing space requirements. Examples: installations where it is necessary to reduce gain to increase stability margin or where the main fluid supply pressure is higher than that required by some of the subsystems. If however, this characteristic is to be built into the basic relay from the very beginning, a more fundamental design approach is preferable.

Any attempt to change relay dimensions to make it conform to a desired nonlinear characteristic is unsatisfactory, since the tolerances involved are in the order of 10^{-4} in. and are difficult to duplicate. It is more convenient to produce nonlinear output characteristics by connecting two or more linear fluid relays in series.

Assuming linear individual gain curves, connecting two relays in series yields approximately a second-order relationship. By using different mechanical displacements for the relays, a wide range of characteristics is obtainable. Figures 16A and 16B show typical configurations using jet and double-orifice

relays. Since either stage can use any one of the three basic fluid relays, the designer has a wide range of solutions at his disposal.

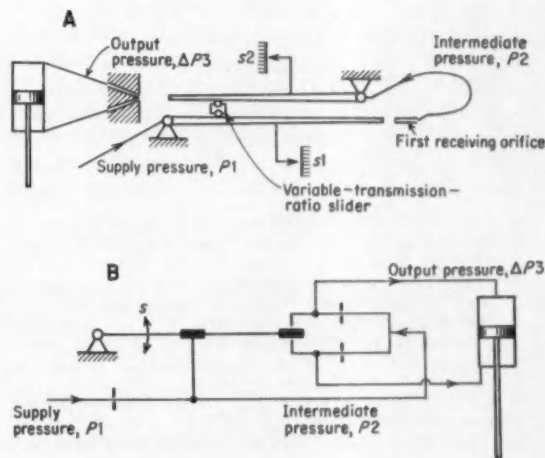


FIG. 16. A—Two jet pipes in series with variable ratio mechanical link in between; arrangement gives nonlinear gain. B—similar series use of double-restriction relays.

6. Making Output Gain Independent of Load

Inherently in fluid relays, gain is a function of supply and load conditions. This dependency can be reduced by overdesigning the equipment so that the required power is only a small percentage of the available power reserve, but this is inefficient and costly. A better way is to use a positive displacement pump with variable output gain, though even here cost and reduced dynamic response characteristics are often prohibitive.

Figure 17 shows a different solution. The four-way valve is provided with a variable orifice a in the supply circuit, orifice plug displacement being directly proportional to error. By maintaining a constant pressure drop across this variable orifice—by means of a differential pressure regulator—the rate of cylinder travel becomes independent of load, and gain can be adjusted by varying the differential.

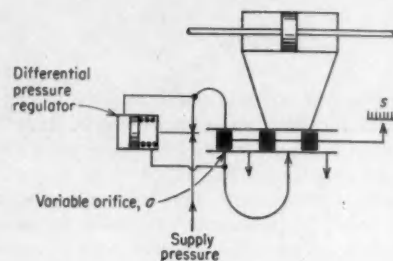


FIG. 17. Variable orifice and pressure regulator make gain independent of cylinder load.

If the pressure differential control valve is used as a relief valve behind a constant volume pump, instead of throttling as shown, this circuit will use minimum power. The reason: pump output pressure will always be at minimum differential above that pressure required by the load on the servo.

7. Varying the Double-Orifice Relay to Increase Capacity

The relay systems discussed so far are modifications of generally used relay designs. It may be profitable now to investigate the possibilities of combining the jet relay principle with the double-orifice relay principle.

In the double-orifice relay the intermediate pressure is modulated by varying the geometry of the first or second restrictions, or of both. However, it is also possible to vary flow rates by dynamic action, as in a jet relay, by adding sources or sinks of fluid energy. This way, not only can the relay output be modulated by a change in pressure, but by adding a source, relay pressure gain and volumetric gain

can be increased. Such a design is particularly useful when the output gain of a relay with fixed supply capacity must be increased.

As an example, consider the standard double-orifice relay in Figure 3, which uses one fixed and one variable restriction. By replacing the second orifice with a jet relay, Figure 18A and 18B, the flow rate capacity of the relay can be increased without changing the supply to the first orifice. The second restriction in this design is replaced by a fluid source and the pressure P_2 is modulated. To go one step further, the upstream orifice A_1 can be replaced by a double jet, as shown in Figure 19.

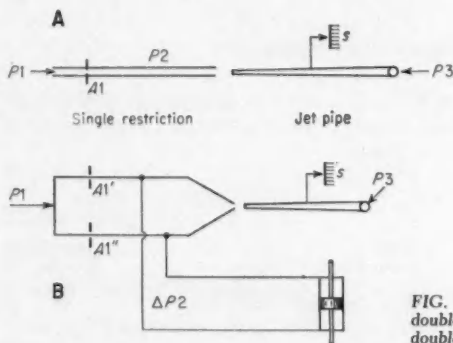


FIG. 18. A—Jet pipe replaces variable restriction in double-orifice relay. B—Push-pull output is obtained by using double jet. Both arrangements increase relay capacity.

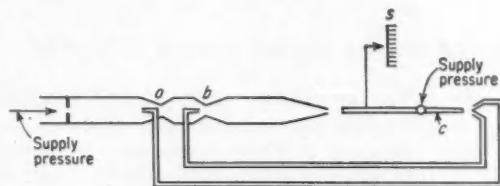


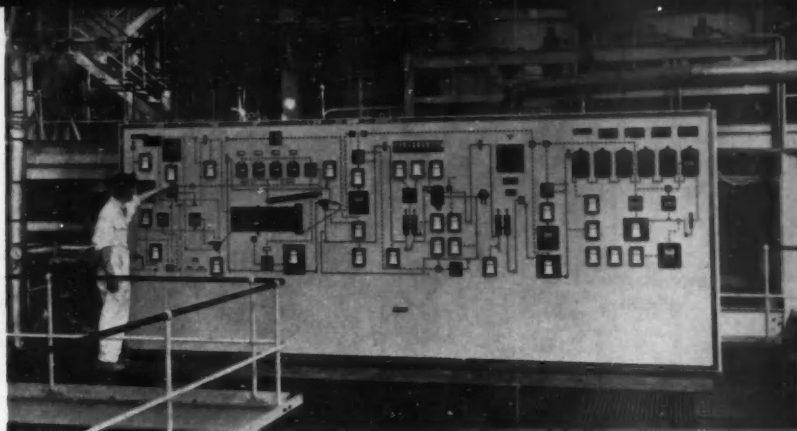
FIG. 19. In another step beyond Figure 18, jets a and b act as injector nozzles energized by jet relay c .

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FIG. 1.
The central control panel mimics the process with the diffusion drum section at the left, the six-stage evaporator at the right.



Multiloop Cascade Circuits Control British Sugar Refinery

E. R. EGLINGTON, Evershed & Vignoles, London

The Wissington sugar factory in Norfolk—one of the most modern owned by the British Sugar Corp.—is the first factory in Europe to use all-electronic control for the operation of a continuous diffuser plant. Three-term controllers and simple force-balance computers provide integrated forward and backward cascade control over the entire process, linking the rate of beet slicing at the start of the process with the output level of the final thick syrup solution.

The mass flow through the evaporator is calculated from a comparison of the corrected in-flow and out-flow. A force-balance computer calculates the mass flow out of the evaporator by signals from a flow transmitter and specific gravity meter in the thick juice main. This mass flow signal is fed to a second computer where it is subtracted from the thin juice flow measurement. The resultant signal is displayed at the control panel, Figure 1, on a divergence indicator showing the positive or negative flow differences from the set-point.

The process

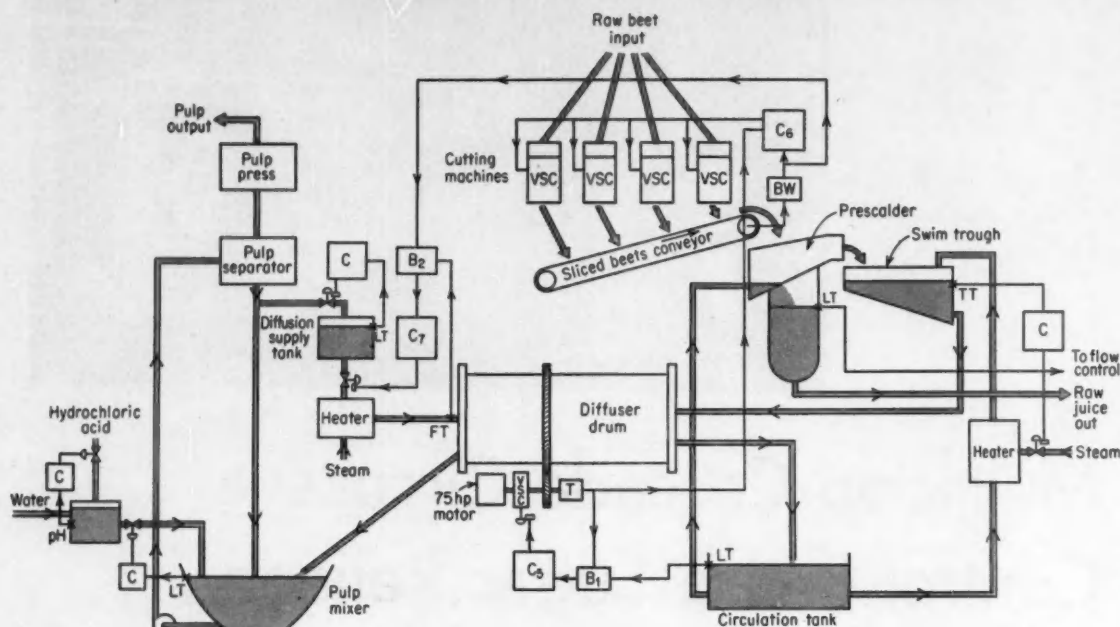
The process, Figure 2, next page, is a continuous flow line with an input of raw sugar beet and an output of 68-percent sugar solution. A seasonal process, the operation starts up every October and runs night and day for up to 120 days, depending on the quality of the sugar beet harvest. It processes 2,400 tons of beet with a sugar content of 15-17 percent each day.

After washing, the raw beet is sliced into chevrons about $\frac{1}{8}$ in. thick and 4 in. long by four slicing machines. Variable speed couplings on the slicer drive motors control the chevron output in accord-

ance with the process throughput. A continuous conveyor carries the slices to a prescaler, where hot dilute fluid from previous immersions of beet heats them. They then pass to the swim trough. Here they are mixed with recirculating extracted juice and an initial sugar extraction occurs. This mix of weak sugar solution and beet slices goes to the diffuser, where a slowly revolving drum transports the chevrons in basket screens against a contra-flowing stream of the juice from the diffusion supply tank. The drum output, containing the pulp and sugar solution, passes to a pulp mixer where it is mixed with additional makeup water to compensate for that drawn off through the diffuser by the later stages of purification and evaporation. To assure total purification despite variations in the beet, dilute hydrochloric acid is added to the make-up water.

From the mixer, the water-pulp mixture passes to the separator, where the pulp is removed for pressing and drying into cattle fodder; the water returns to the mixer via a secondary circulation loop. A take-off point in this return line feeds the diffuser tank supplying the weak solution against which the chevrons travel in the diffuser. The raw juice from the diffuser passes to the circulation storage tank prior to being drawn off to the filtration section.

Impurities of resin and gums in the raw juice are removed by adding lime in a solution of calcium hydroxide. A density recorder controls the addition of water to highly concentrated lime and a slow speed bucket wheel adds the solution to the raw juice. Excess lime is neutralized by carbonation: the amount of CO_2 added is regulated by pH control of the purified sugar to maintain slight alkalinity. Two-stage filtration then removes the



precipitated impurities and chalk before passing to the thin juice storage tank. From here the juice is pumped to a six-stage evaporator to reduce the water content so that the juice arriving at the thick juice storage tank will be 68-percent sugar. This is drawn off to vacuum crystallizing pans.

The controls

Integrated control, also shown in Figure 2, is maintained throughout the process by two main multiloop systems. One system, at the right, controls the juice flow through the two filters and the evaporator to the thick juice storage tank. Each valve is positioned by two variables:

- ▶ Flow to the thick juice tank by the tank and evaporator levels.
- ▶ Flow to the evaporator by the thick and thin juice tank levels.
- ▶ Flow to the thin juice tank by the prescaler and thin juice tank levels.

In the second multiloop system, at the left, the diffuser drum speed controls the associated rate of raw beet slicing and the intake of make-up water to the diffuser.

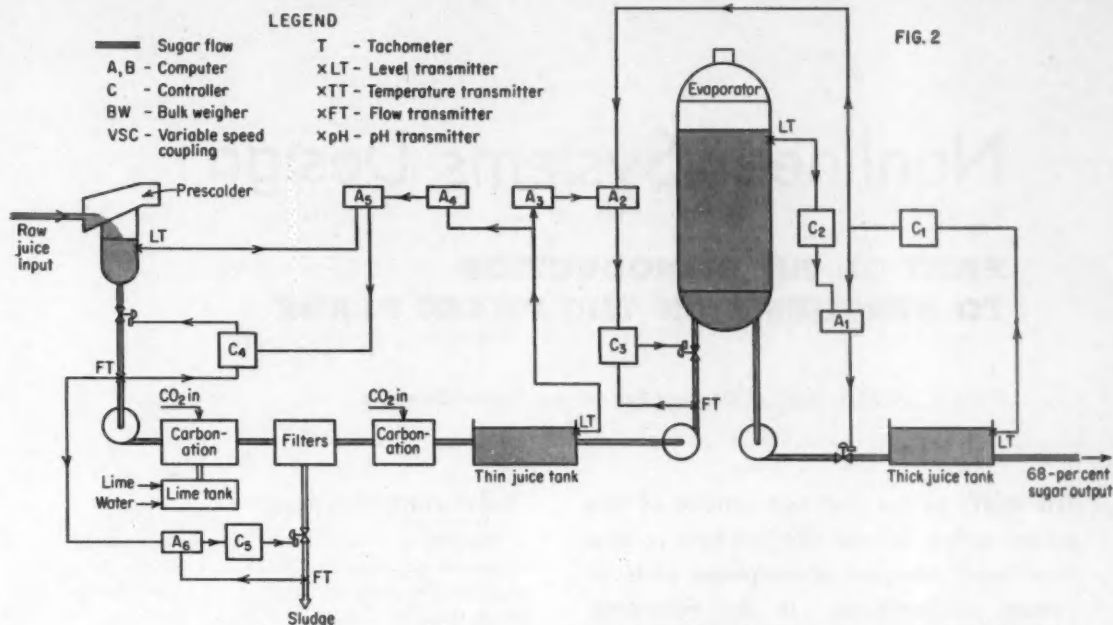
Simple force-balance computers provide the algebraic computation between two variables to adjust the set-points of the cascade controllers in each loop. In the computers, two coils in a moving-coil force-balance mechanism are fitted to the ends of a pivoted beam and move in a magnetic field. One coil receives the input signal to unbalance the beam and operate one of a pair of contacts near the output coil. The contacts modify the grid potential of a tube circuit connected to the second, or output, coil. Thus the current in the output coil is adjusted to rebalance the beam (the opposing force is propor-

tional to the current and its associated permanent magnet). If the permanent magnet is replaced by an electromagnet in series with the coil, then the restoring force has a square-law relationship to the restoring current. Suitable coil interconnections permit other computations.

In the flow control loop, Figure 2, six such computers are used. The first of these, A_1 , regulates the flow to the thick juice tank according to both tank and evaporator levels. Level transmitters in the thick juice tank and evaporator feed standard 0-30-ma signals to two three-term controllers (C_1 and C_2). As the level in the evaporator increases, the level transmitter output falls. This opens the flow valve between the evaporator and the thick juice tank. The thick juice tank level transmitter actuates the controller (C_1) whose desired value is set 9 in. below the tank top. Its proportional band is adjusted so that the upper 18 in. in the transmitter range gives an output of 0-15 ma.

This output and that from the evaporator controller are summed in computer A₁, whose output actuates the flow valve. When the thick juice tank level rises, the valve closes. Consequently the level in the evaporator rises, too, giving a reduction in the output from the evaporator level transmitter. This opens the valve. Interaction between controllers continues until the output from the evaporator transmitter is zero, indicating that the evaporator is full. At this point the output from the thick juice tank controller takes over and positions the valve solely in accordance with the thick juice level. Alarm circuits operate if both the evaporator and the thick juice tank fill to their limit.

A stage further back in the process, flow into the evaporator is again governed by two variables—the



Sugar Juice Purification and Extraction

levels in the thick and thin juice tanks. A single control loop, comprising a diaphragm transmitter with its controller C_3 operating the flow valve, set the juice flow at the desired 100 tons per hour. Two computers (A_2 and A_3) adjust the set-point of the controller and hence the flow according to the computed values of the two tank levels. A level transmitter in the thin juice tank provides a 0-30-ma signal for a 10-ft level change. Within the bottom 2 ft of this range it is essential that the thin juice tank have an overriding control on the flow valve to prevent the tank being emptied and the discharge pump being left without a head on the suction side. To achieve this, the computer A_3 operates on the equation: $\text{Output} = 5(L_1 - 24)$, where L_1 is the thin juice level transmitter output.

At all levels above the bottom 2 ft mark the transmitter output is less than 24 ma and hence the computer output is zero. When the level falls below 2 ft the transmitter rises from 24 to 30 ma over this bottom 2 ft range. The computer converts the multiplying factor of 5 to a full 0-30-ma signal.

The second computer, A_2 , sums this 0-30-ma signal and the output signal from the thick juice tank level controller. The computed output adjusts the set-point of the thin juice flow controller C_3 so that flow is reduced when the level in the thin juice tank falls to within the bottom 2 ft or the level in the thick juice tank rises to within the top 18 in.

The flow between the prescaler and the thin juice tank is regulated by the levels of the prescaler and the thin juice tank. The output from the thin juice tank level transmitter feeds computer A_4 , which operates like computer A_3 to give an output swing of 0-30-ma for level change in the upper 2 ft of the tank. A second computer, A_5 , sums this signal with

that from the prescaler level and the total operates the cascade circuit of the raw juice controller C₄.

In the second multiloop system the diffuser drum speed controls through subsidiary loops the production rate of raw juice from beet. Speed variation of the diffuser drum is controlled by servo-driven diaphragm positioners on the hydraulic coupling between the drive-motor and the drum. Controller C_5 controls the diaphragm positioners from a summation of drum speed and circulation tank level. This summation is made in computer B_1 , whose inputs are taken from a tachometer mounted on the diffuser drum drive shaft and from the circulation-tank level transmitter. The computation constants reduce the drive speed of the drum by 50 percent for a 2-ft rise in the circulation tank. Limit relays in the control circuit prevent the motor speed from being reduced below 60 percent so that diffusion cannot be stopped when on automatic operation.

The tach output feeds the cascade circuit of the cutting machine speed controller, C_6 , to regulate the cutting of the raw beet in accordance with the drum speed. The input to this controller is from a continuous-belt weigher mounted on the conveyor measuring the weight of sliced beet fed from the cutters to the prescalder. The controller adjusts variable speed couplings on the four cutting machines.

The weight of sliced beet also regulates the amount of makeup water added to the diffuser. The belt weigher output feeds a computer B_2 , which also receives an input from the diffusion water flow transmitter. The difference value of these signals appearing at the computer output controls the water-supply intake in a fixed ratio to the weight of beet arriving at the diffuser. A simple adjustment of shunting one computer coil yields different ratios.

Nonlinear Systems Design

PART III: AN INTRODUCTION TO SYNTHESIS ON THE PHASE PLANE

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THE GIST: In the first two articles of this series, author Gibson showed how to construct and interpret phase-plane plots of system performance. In the following pages, again with the practical system designer in mind, he describes the present state of synthesis techniques for nonlinear systems, pointing out the advantages and limitations of the phase-plane approach.

The first article of this series discussed methods of obtaining the phase portrait of a control system, the second article, the interpretation of the phase portrait. This article provides a brief introduction to the philosophy of system synthesis. Unfortunately, no elegant and general treatment of the synthesis problem exists. Solutions must be catalogued case by case and a method that proves successful for one system or type of nonlinearity may fail when extended to a different system. The examples given here simply illustrate methods of attack rather than complete design procedures.

In spite of the fact that derivation of an optimum controller by direct synthesis is seldom possible, the phase-plane point of view remains a valuable tool. Even where an empiric or a computer model of the system is used, the phase plane will reveal relative damping, the type of system response, and the presence or absence of limit cycles.

Of the various nonlinear systems for which design techniques still do not exist, the most important is the off-on controller or relay servo. Kochenburger and Stout (Refs. 1, 2, 3) have discussed the relay servo and several other nonlinear systems, along with possible optimizing techniques. A technique developed originally by Hopkin (Ref. 4) and mentioned by Stout (Ref. 3) will be reviewed briefly here because it appears capable of considerable generalization.

Relay controller design

Several investigations (Refs. 5, 6, 7) have shown that the primitive method of causing the relay to reverse the output element as error changes sign, at a so-called linear switching boundary, does not yield an optimum relay control system (where optimum is defined as the minimum response time for a transient). Instead, optimum response requires a switching curve that depends on: the state of the system, imperfections in the relay, and perhaps the type of input. Wherever a properly designed switching curve has been used, considerable improvement in response has been reported. It should be pointed out, however, that the switching curve is usually designed to optimize the system for step function inputs and even with this restriction, possible oscillatory modes have been discovered (Ref. 6).

Hopkin shows that any physical servomechanism has very definite physical limitations that cannot be exceeded. For instance, a positioning system exhibits a maximum torque or force limitation that depends on the rating of the power unit. There will also be a maximum velocity limitation, but this is not usually restrictive. Figure 1 illustrates these limitations on the phase plane of a system output. For no limiting, the system would move from an initial position c_0 to the desired position c_1 in minimum time if it instantaneously accelerates to infinite velocity, moves from (∞, c_0) to (∞, c_1) and decelerates in zero time. However, the maximum signal applied to the power element imposes a velocity limitation in any physical system, so that the phase plot in Figure 1B is slightly more realistic.

While this trajectory is limited to a finite time, it still requires an infinite force for acceleration and deceleration. Specifying a maximum force produces a trajectory like that of Figure 1C. Herein it is assumed that the maximum force available is the same for both acceleration and deceleration and that all the force is applied to accelerating system inertias. Stout (Ref. 3) has shown that these curves are segments of parabolas. Thus, the time required in Figure 1C represents an absolute minimum for the given maximum force. Actual systems now may be compared to this optimum system.

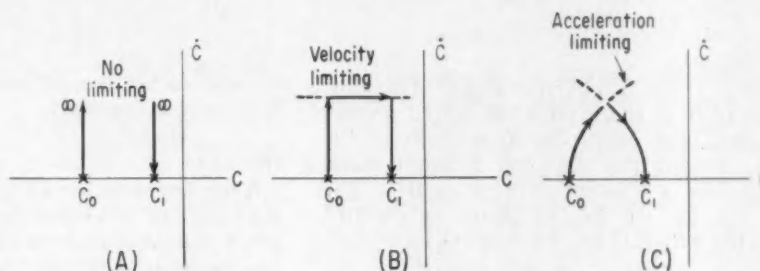


FIG. 1. Optimum phase trajectories for various types of limiting.

It should be evident now why modern servo development tends so strongly toward the relay servo. At least for the simple step input, the relay is potentially the best possible system, for during the entire control cycle the power element is driven at its maximum capacity and close to minimum time is required. The problem, of course, is to determine the optimum time at which to reverse the relay.

In general, this is not simple. However, if, for example, it is assumed that all the force is available for deceleration, the maximum deceleration curve becomes the switching line shown in Figure 2. The various r_0 's shown represent initial errors to step function inputs. The moment of optimum switching occurs when the acceleration curve intersects the optimum deceleration curve. Since this curve is a function of e and \dot{e} , it is possible to design a nonlinear network that precedes the delay and produces this curve at its output.

In a practical system the relay might connect the armature of a dc motor to $\pm E$ volts as shown in Figure 3. Here torque is proportional to I_a , which builds up as an exponential due to the time constant of the armature resistance R_a and armature inductance L_a . In this case it might be advisable to move the switching boundary forward of the maximum acceleration curve by one or two time constants (Ref. 5). The actual spacing on the (\dot{e}, e) plane, for any value of Δt , may be found by using Equation 8 in Part I of this series. Figure 4 shows the shape of this new boundary.

This, then, is a way to use the phase plane for designing a higher-order system. The design would be incomplete, however, if, after the nonlinear controller had been chosen, system stability was not checked by a method such as Kochenburger's describing function technique. Furthermore, optimization for step function inputs is no guarantee of optimum performance for other types of inputs.

A general approach

The above procedure for designing corrective networks for relay controllers constitutes a rather unique approach in that it permits optimization of a whole

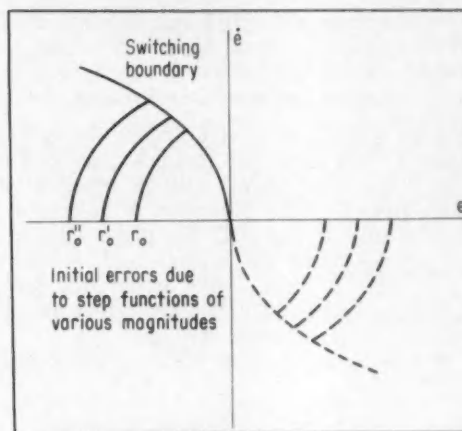


FIG. 2. Optimum switching boundary for an ideal relay servo with force limiting

class of nonlinear systems. Unfortunately, no such simple procedure exists for most other classes of systems. As a general approach, however, three rather loose rules will serve to guide in the synthesis of satisfactory second-order nonlinear systems. This is less restrictive than it first sounds, for many control systems can be adequately represented by a pair of damped quadratic roots.

Rule I

Construct a family of phase trajectories for the range of initial conditions expected and for various values of parameters under the designer's control. A general plot of this type was shown for the automatic phase-control system discussed in Part II of this series (Figure 3).

For a more detailed example, consider the system with backlash in the output gear train, also mentioned in Part II. This system consists of a difference device and amplifier, both considered perfect, a motor with an integration and a time constant, the output gear train, and a position pick-off. Assume that in Equation 36 (Part II), describing the system, $K = 100$ rad/sec, $T = 0.01$ sec, backlash in the output gear train occupies 0.1 rad, and that the gear ratio is included in the constant K .

Let the initial conditions cause the trajectory to

start at A in Figure 5 with zero input. The locus progresses to B, at which point the output reverses and the loop opens while the output traverses the backlash. During this time the system operates open-loop with a constant error of $(-B)$. The transfer, c/e , may be used to obtain, by standard methods, the output C for this constant input:

$$C(t) = -KB [tu(t) - Tu(t) + Te^{-t/T}] \quad (37)$$

Solving for the time required for $c(t)$ to traverse 0.1 rad, and substituting this in the expression for output velocity,

$$V(t) = -KB [u(t) - e^{-t/T}]$$

yields

$$V(t) = -100 B [1 - e^{-0.001/0.01}] = -9.5 B$$

for the velocity at point C, where the backlash is taken up and the system resumes closed-loop operation. The same process must be repeated for the jump from D to E. Note that if the error at D is smaller than it was at C the phase-plane locus is proceeding toward the origin. Still, a limit cycle could exist at some region inside this particular trajectory and for the unfamiliar system the calculation should be followed through.

It is apparent here that the phase plane organizes

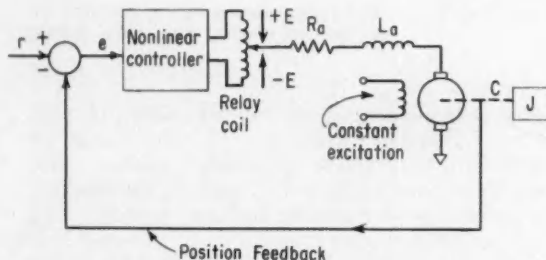


FIG. 3. An ideal relay driving the armature of a dc motor connected to an inertia load.

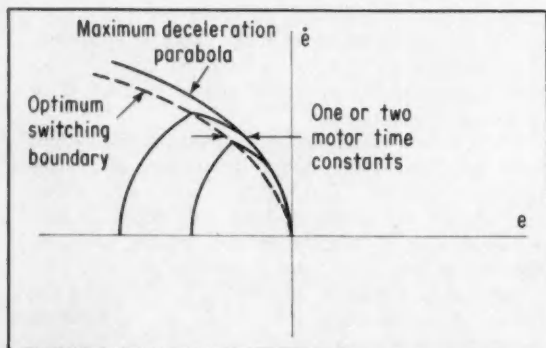


FIG. 4. Switching boundary for motor with armature time constant.

the solution but does not simplify the actual amount of calculation required.

Rule II

Next, determine the range of conditions that permit instability or limit cycles to occur. If possible, adjust the parameters to eliminate these undesirable modes of operation. In the automatic phase-control system, for example, the loop gain can be raised (Ref. 8) so that operation takes place in the small error or approximately linear region. A controller for satisfactory phase margin or M peak can then be designed by linear techniques. In the system with backlash, should a limit cycle appear, response can be improved by adding more viscous damping. In the case of saturation, gain may sometimes be increased to reduce error and permit operation in the linear region.

In these examples, and in other cases where the nonlinearity occurs in a low-power portion of the loop, such simple adjustments may prove suitable. Usually, however, the fault lies in the output or power element, where correction by such simple methods is either very expensive or impossible.

Rule III

Design a corrective network to improve system performance. With the exception of the methods already described for designing the on-off controller, no general synthesis technique exists that suits all nonlinear systems in a given class. The following proposed methods, however, apply to a certain number of systems.

Method 1. Cancel the nonlinearity by constructing a nonlinearity with a complementary shape and insert it in the loop. This technique may find use in a few practical systems but has definite limitations. If, for example, the nonlinearity is saturation in the output element, the only way to eliminate it is to substitute an element of a higher-power rating. It is impossible by any closed-loop technique to extract more power from the output element if it is already delivering its maximum to the load. Even when the nonlinearity occurs in a low-power unit, such as an electronic amplifier, it is usually more economical to redesign the unit than to design a nonlinear compensation network.

Method 2. If the nonlinearity is a severe function of error amplitude it may be impossible to design a network that eliminates limit cycles throughout the operating range. For this case some designers have suggested dual mode systems that switch between two controllers, with separate gain and frequency functions depending on the error. Dual-mode controllers can also provide a high slewing velocity for large step functions and a tight, accurate system for small values of error.

The technique of adding special circuits for special inputs rapidly gets out of hand, however, and

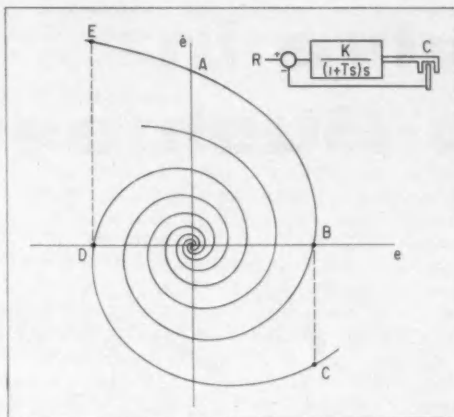


FIG. 5. Phase portrait of a simple positioning with backlash in the output gear train.

the additional circuitry may be more complex and expensive than the entire original system. Quite often, too, a much simpler device can provide the same results. In the slewing circuit, for instance, a simple velocity friction clutch works just as well as an elaborate dual-mode servomechanism, and is much less expensive.

Method 3. Kuba and Kazda (Ref. 9) suggest a method of arriving at a close approximation, for any nonlinear servo, to the optimum response of a relay servo as defined by Hopkin. The method involves the design of rather complex compensating networks when the order of the system is two or higher, but appears to merit further investigation. This procedure has been considerably simplified by Chang (Ref. 11).

Method 4. Macmillan (Ref. 10) has outlined a technique that is somewhat more sophisticated than operation on the phase plane. Since the latter technique eliminates time as an explicit function, it may be considered a condensed method of presenting overall system behavior. The Macmillan method of characteristic curves goes one step further: a piecewise linear system may be described within any one region by a linear differential equation and, assuming a stable system, the maximum amplitude a system will attain may be determined by its initial velocity as it enters the region. Macmillan thus develops a curve relating maximum amplitude of a transient swing to the initial velocity of the system as it enters a linear region and, likewise, a curve relating final velocity as the system leaves the region to the maximum amplitude attained in the region. He plots maxima and zero crossings rather than complete trajectories, as on the phase plane.

This is perfectly acceptable in second-order piecewise systems, and fortunately quite a few practical systems may be approximated within these restrictions. Equalizer design is accomplished essentially as on the phase plane. The major advantage seems

to be the presentation of the essential features of a system by several characteristic curves that are as difficult to come by as the entire phase portrait. The gain is thus in presentation, not calculation.

Macmillan maintains that compensation is simpler, because limit cycles are revealed by the intersection of the curves, and the effect of a network in shifting or eliminating the intersection can be quickly seen.

Limitations

The major advantage of the phase-plane method is its ability to display, on a single plot, overall performance of a nonlinear system. Its major disadvantage is that in general, it can only be applied to second-order systems or systems that can be approximated by a quadratic. Considering the overall performance of a nonlinear system is one way to avoid bogging down in the details of a particular nonlinearity. From this point of view the phase-plane approach is philosophically proper and the Macmillan characteristic curve method a still further advance.

The next step for the reader interested in continuing his work in nonlinear control systems should be to read a book like *Introduction to Nonlinear Analysis* by Cunningham (Ref. 12) to learn other analysis methods. Cunningham will be appreciated by the engineering reader because of his many worked-out examples and clear, concise style. The reader then might introduce himself to control systems by reading Cosgriff (Ref. 13).

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How to Survive in the Systems Business

Yes, how to survive. The reality of this problem is known to every company engaged in the systems business. While there is little quarrel with the fact that money can be made in this field, achieving success requires a lot of foresight and patience, and a willingness—if it becomes necessary—to change your whole way of doing business.

In this sequel to his article on systems bids (Ref. 1), Author Bell, a systems consultant, explains why engineering in this field is unique and marks the most dangerous pitfalls.



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If you are willing to forgo immediate profits in the systems business for long-range prospects, if you appreciate how much money is required to successfully participate in this business, and if your organization has the financial stability that will permit operation in the red for several years, then your future in systems engineering is exceedingly good.

The systems company is unusual as a business enterprise because it is at the same time broad in its activities and specialized. It is broad because:

- it includes such diverse products as data loggers and optimizing controllers for the process industries, coil classifiers for the steel industry, numerical control systems for steel and paper rolling mills and for machine tools, high-speed data-recording systems for test facilities, etc.
- the costs of these systems range from \$5,000 to \$500,000
- their operation depends on electrical, electromechanical, mechanical, or electronic devices
- their chief components, far from being individualized, are often the chief components of the familiar general-purpose computer: digital circuitry, electronic counters, and a logic system

And the systems business is specialized because, for all its broadness of scope, of costs, and of components, it produces custom-designed products. That is, these products, while they may be assembled from standardized or semistandardized components, are essentially engineered to meet particular requirements.

What are the factors facing a systems company that limit immediate profit-making? Let's answer that question by looking at the five important organizational areas

of a systems business, paying particular attention to the way each one is influenced by the demands of special customer requirements. The five areas are: Sales, Engineering, Manufacturing, Maintenance, and Finance.

Sales

Systems selling demands a wide background of experience. To be successful, the systems salesman must be conversant with the noise and filtering problems of the analog domain; the construction and programming of digital computers; he must know servomechanisms, the theory of feedback control, logical design, and operational analysis; and he must be able to discuss with equal facility the problems of a blowdown wind-tunnel, an oil refinery, or a steel mill.

Men with the necessary diversified background and the ability to sell systems command a high salary. These high salaries are one of the many things that cumulatively produce a very high overhead. To hold down this overhead, a systems company may supplement its regular sales staff with sales representatives. The theory: these representatives, even though novices in systems, should be useful for finding business. And the sales reps themselves are enthusiastic: commissions or finder's fees for selling systems at prices of five or six figures are sizable incentives.

The representative soon finds, however, that these fees are hard to come by. What is more, he has put in a great deal of time and effort only to find his income decreasing because he isn't selling his off-the-shelf items. Finally he decides that he is wasting his time. Which drops the sales problem back in the manufacturer's lap.

Probably the most significant hidden cost in systems selling is in educating the customer. It is not sufficient to show a photograph of the device, list its specifications, and explain to the customer why your product is better

than the competition's. And since it is a system that must be sold, there is not a single best design: instead, there are many options.

It's a different world

In preparing a sales proposal and in selling that proposal, the salesman must both explain and justify the hardware employed. If a tape recorder is used in the system, any one of several machines can be selected. If a sensing device is used as an input, it can be optical, magnetic, or electromechanical. Within the framework of any single set of specifications, a very wide range of system costs may result (Ref. 1). What is more, proposals are lengthy; they are written for specific requests, use a minimum of "boiler plate", and cost a lot of money to prepare.

The salesman's competitors, of course, must justify their systems, too. And when the would-be systems buyer has succeeded in wading his way through all the proposals, he often finds that what he wants in a system is impossible. Every supplier, in justifying his own system, has explained why alternate components, devices, or ideas are unacceptable. Since it is very unlikely that the same system hardware will be touted by all bidders, the result is, for the buyer, the "exposure" of the unsuitability of all concepts! The buyer's defense may be to select the more reasonable proposals and schedule individual conferences with the bidders. These educational sales junkets add to the selling cost.

In an older, better-established industry, if a good proposal and adequate sales presentation has been made, the salesman can be optimistic about getting the contract. Not in the systems business, however! By this time thousands of dollars have been invested in systems engineering, proposals, travel expenses, and wining and dining the customer. A novice to systems selling may be surprised to learn that fishing trips and parties are considered by some companies necessary sales expenses.

Some booby traps

This competition doesn't bother him, however. He is certain that he is offering the best system, his price is fair, and the customer seems to like the equipment. The contract is in the bag—until—

Possibility one: At this point the customer knows a great deal more about systems than he did before asking for bids. He's been exposed to a lot of salesmen and a lot of hardware concepts. How would you, as the salesman, feel if the buyer turned down all bids and then proceeded to issue another invitation to bid—an invitation that included hardware concepts pirated from your bid and the bids of other manufacturers, too?

Possibility two: The prospective buyer may spend months negotiating, and then throw out all bids and set up his own systems operation, in direct competition with all of the companies that have divulged their systems concepts, equipments, and circuit details in their effort to win the contract.

Possibility three: You say your quoted price is fair and reasonable? Then you may have priced yourself out of the market! Companies eager to get into the systems business are quite willing to buy a contract by knowingly quoting a figure that will result in a direct loss. Nor is this unreasonable. Certainly, working on a contract, building hardware to be sold for any figure is less expensive than doing a complete development job yourself.

Engineering

Successful systems engineering imposes an extremely difficult discipline upon an engineering group. Because this discipline is in many respects different from typical electronic engineering, it is not easy to successfully direct the engineering effort.

It is obvious that a large amount of engineering effort must go into every system produced. Therefore, any standardization of circuitry or components that will minimize engineering time will also cut system costs and aid in producing profits. The trick is to achieve standardization without freezing designs. This is like asking the engineer to stand up and sit down simultaneously. Yet flexibility must be maintained in designing systems.

Direction can be given to the engineering effort if there is a clear understanding of what variables should be optimized in the design. Minimum circuitry, minimum number of connections, minimum number of components, and minimum packaging size are the usual design objectives; but they are not the objectives of systems design. The savings achieved in this way reflect themselves in volume manufacturing, not in engineering time. Again there is the fundamental fact that the systems business is not a mass-production business.

The design engineer should optimize, above all else, reliability; and after reliability, accuracy and operating ease. (The importance of these three variables becomes crystal-clear once systems are installed in the field and the supplier is required to maintain them.) Lastly, and most important to cost, the designer must minimize engineering time required to deliver a system. And there is the challenge: no compromise can be made with reliability and accuracy; quick and dirty design is out of the question; yet, specialized custom design must be achieved with a minimum of engineering effort.

Don't sell R&D short

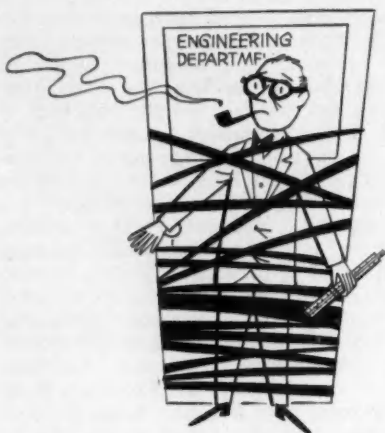
A major expense for the systems company is continuing R&D. No company can hope to assume a position of importance in the systems field or to remain a successful contender for contracts unless it recognizes research dollars as a continuing necessity. Most companies would agree that R&D is necessary and would affirm their willingness to make the investment required. Where many of them err, however, is



in underestimating the size of this dollar requirement.

Investment in component evaluation is also a heavy engineering expense. Customers want to place system responsibility on a single supplier, and there is only one way for this single supplier, the systems maker, to guarantee performance of each component: he must buy and life-test competitive units. More dollars gone!

A major hazard in the engineering department is overoptimism. Systems are basically large equipments—integration of different components and devices to do a single unified job. To say that a system has a thousand times as many connections as a television set is not to say that it is a thousand times more complicated, but rather 10,000 or perhaps even 100,000 times



more so. For the relationship between increased size and complexity is not linear; it is a power function of distressingly high order.

Manufacturing

The engineer is not the only one who must redefine his objectives if he wants to stay with systems; the production man must, too. One of the surest ways to lose money in this business is to hire production men with good records in mass manufacturing, for the paper controls they are bound to apply to systems construction will result in a red-tape paper mill that will slow down production and produce exorbitant costs.

No compromise with quality is possible, yet quality control must be achieved, and with a minimum of complication. Elaborate drafting must be avoided like the plague; wiring call-out sheets must be used instead of circuit diagrams wherever possible; complex wiring harnesses must be discarded in favor of point-to-point wiring with or without ducts. Small-lot production must be perfected—and at reasonable costs.

Because until it is recognized that the systems business is job-shop manufacturing (and sometimes it takes a lot of convincing), and until production is organized and managed as a job shop, profit dollars will be lost.

Maintenance

Well-established companies with nationwide sales and service organizations have a powerful advantage over the smaller company without these facilities. For un-

questionably, one of the major factors in a customer's selection of a supplier is the ready availability of competent service engineering.

Supplying maintenance is a particularly difficult problem for companies just getting into systems work. A few installations of equipment in widely scattered geographical locations spell very high maintenance costs. The establishment of field service offices in different parts of the country is an indicated requirement. Such service activities have very little chance of paying for themselves until there is a wide-enough base of equipments to support them. In the meantime, they take profit dollars.

And meanwhile, too, the service-engineering manager soon decides that he has the most thankless job in the company; they can't do without him—yet no one wants him, either. One conclusion: more overhead!

Finance

Accounting in the systems company must also respect the job-shop nature of the business. Attempts to force mass-production accounting methods on a systems operation are doomed to failure. The accounting system must be flexible and fast, so that management has daily cost control over work in progress. This means being alert to the following facts:

- smaller systems may have a turnover time of only a few weeks
- large systems may take months for assembly, plus more weeks or months for final check-out and evaluation before delivery
- once systems are delivered and payment received, there is still the probability of additional field-effort costs, promised under the company's guarantee

A controller new to the systems business may find great difficulty in relating accounting requirements to the practices of the business. It is hard for him to get a firm fix on what is the company problem. A real understanding of the systems business requires a good grasp of the engineering concepts involved, which may be difficult for a financial man. All too often the controller may find himself snowed by an enthusiastic engineering department and an eager sales group.

The biggest financial problem is holding the cost line. The controller can isolate and catalog the cost factors that must be included in realistic prices. But if these cost levels are accurately established, sales may feel that the company is being priced out of the market. The real problem here is one of management directive. How soon must a profit be shown? What write-off periods can be used? What profit margins are set as goals?

Ultimately, there will be a severe shakedown of companies in the systems business. Companies seeking a fast and easy buck will be gone, victims of their own inferior equipments, and those left will be the ones with the financial stability and technical competence to have lived through the formative period we are now in. These companies will be in a position to capitalize on electronic systems, which will have become a multi-billion-dollar industry. Then profits will be made.

REFERENCE

1. HOW TO EVALUATE CONTROL SYSTEM BIDS, William D. Bell, "Control Engineering", December 1957, p. 87.

A Graphic Solution for Thermistor Characteristics

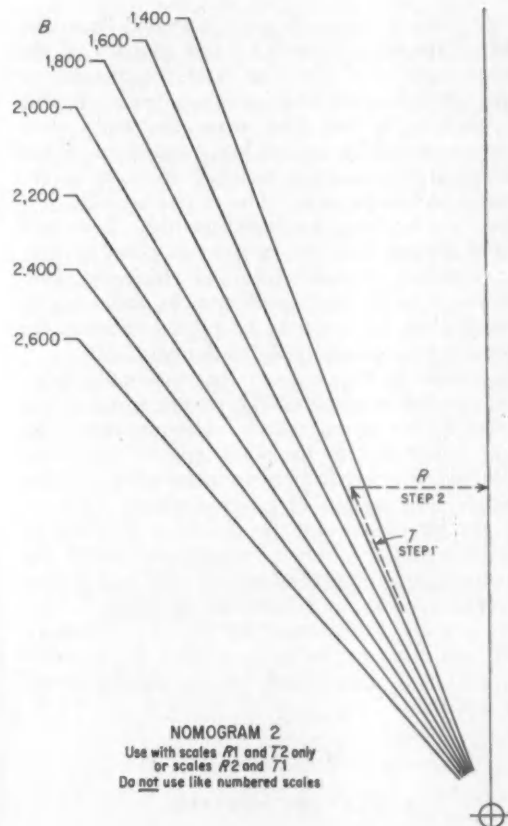
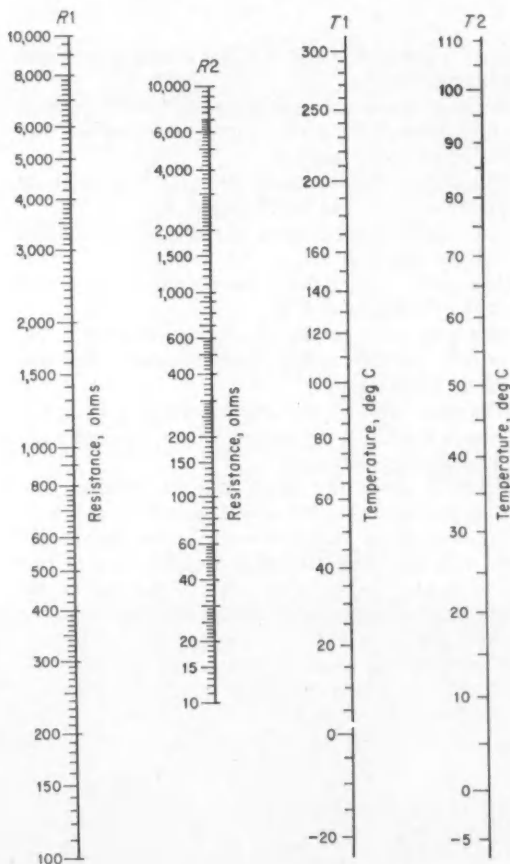
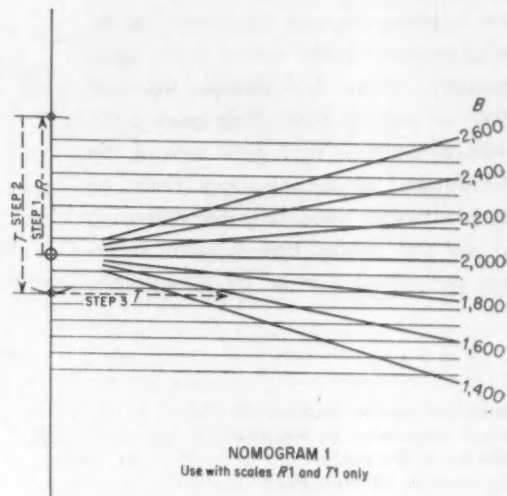
HARRY G. PARKE, Marine Electric Corp.

Calculation of thermistor characteristics from given data or measurements generally requires that tedious work be done by skilled personnel. These calculations have been reduced to the two nomograms on this page.

TO FIND TEMPERATURE CHARACTERISTIC, B (NOMOGRAM 1): Measure resistance at two temperatures. Take distance between two resistance readings from scale R1 with dividers; lay up as a vector from origin on vertical axis (step 1). Take distance between two temperatures from scale T1 and lay down from tip of resistance vector along vertical axis (step 2), and then out perpendicular using horizontal lines as guide (step 3). Tip of vector 3 lies on slant line representing correct B value.

TO FIND RESISTANCE AT ANOTHER TEMPERATURE (NOMOGRAM 2): Take distance between temperatures with dividers; lay out from origin along correct B line as a vector (step 1). From tip of vector 1, drop line perpendicular to vertical axis. Take length of vector 2 with dividers and lay off on proper resistance scale from known resistance to find unknown. Use scales R1 with T2, or R2 with T1 for this nomogram.

Nomograms copyright by Marine Electric Corp.



Servo Control Improves Precision Gear Hobber

Gear hobbers become inaccurate as errors accumulate in the master worm gear, especially when the master transmits power as well as controlling gear pitch. Here's a machine that gets around this difficulty by servo-controlling from an accurate master used only for reference and not for power transmission. It reduces accumulated error by 75 percent.

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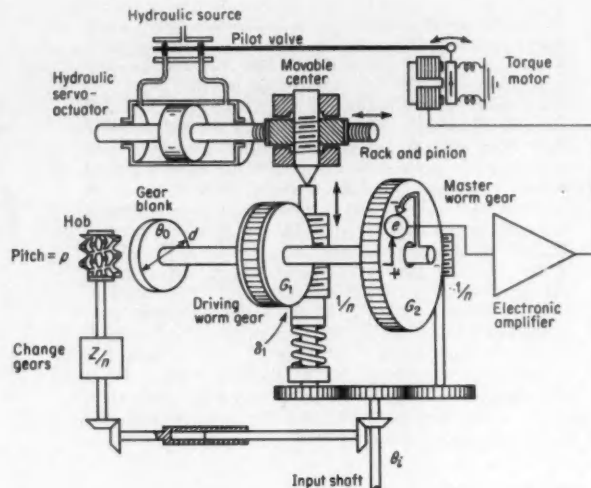


FIG. 1. Servo-controlled precision gear-hobbing machine.

The pitch accuracy of gears generated by a gear hobbing machine depends on the accuracy of the master worm gear. In most machines, the master worm not only serves as an angular reference for the generated teeth, but also drives the main work spindle or worktable against heavy resistance. Thus the angular transmission accuracy decreases as the worm wheel teeth wear. The servo-controlled precision gear-hobbing machine described here gets around this problem with two special worm-and-gear combinations. A heavy-duty pair efficiently transmits power to the main work spindle, and a highly accurate master pair acts as the angular reference for controlling the circular pitch of the gear teeth.

As shown in Figure 1, an electrohydraulic servo transmits the rotation of the master worm wheel to the driving worm wheel. The driving worm wheel is fastened to the work spindle, while the master worm wheel is fitted to move relative to the spindle. The output of an error-sensing device e between the master and the spindle is amplified to drive the torque motor. Vertical position of the driving worm is controlled by the rack and pinion, hydraulic cylinder, and hydraulic servovalve. This permits axial displacement of the driving worm shaft, correcting for errors in angular displacement of the driving worm wheel. If the angular correction is v , then

$$v = G_0 e$$

where G_0 equals K/s and K is the overall gain of the servomechanism.

Defining the system parameters as follows permits the derivation of the mathematical relationships that define system performance:

- the angular displacement of the hobbing-machine input shaft is the input signal, θ_i
- the angular displacement of the gear blank is the output signal, θ_o
- the pitch error angle of the driving worm wheel is the disturbance, δ
- the gear ratio of the driving worm gear is G_1 equals $1/n$ (but including disturbances δ because of its pitch error)
- the gear ratio of the master worm gear is G_2 equals exactly $1/n$ (because of its required high accuracy as a reference)

Figure 2 shows the block diagram of the gear-cutting process using the above parameters. Comparing the linear displacement of the hob-cutter teeth with the circumferential displacement of the gear to be cut gives the pitch error of the gear as the difference e between them. By simplifying the block diagram to that of Figure 3, the output angular displacement of the work spindle θ_o and the accumulated pitch error of the cut gear can be calculated as follows:

$$\theta_o = \frac{1}{n} \theta_i + \frac{s}{s + K/n} \delta \quad (1)$$

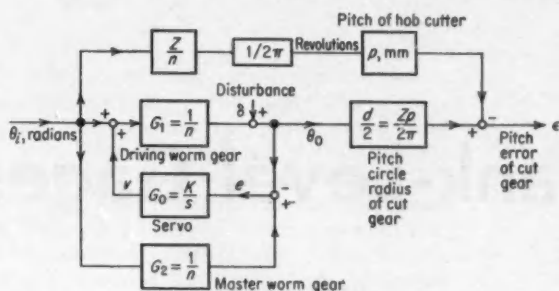


FIG. 2. Block diagram of gear cutting process.

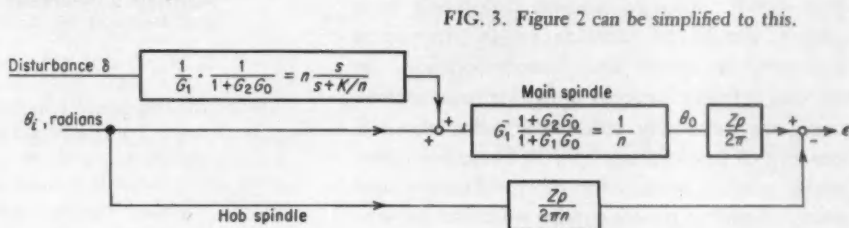


FIG. 3. Figure 2 can be simplified to this.

$$\epsilon = \frac{Zp}{2\pi} \left(\frac{s}{s + K/n} \right) \delta \quad (2)$$

where Z = number of teeth on the cut gear
 p = circular pitch of cut gear
 s = differential operator d/dt

In general, it can be assumed that the disturbance of a low-accuracy worm wheel can be represented by a two-period periodic function with respect to the angular displacement of the work spindle. The two periods can be expressed approximately as follows:

$$\delta = a_1 e^{j\Omega t} + a_2 e^{j(n\Omega t + \phi)} \quad (3)$$

where Ω = angular velocity of main spindle in rad per sec
 a_1 = amplitude of the angle transmission error of the driving worm gear whose period corresponds to one revolution of the worm wheel
 a_2 = amplitude of the error whose period corresponds to one revolution of the worm shaft.

Substituting Equation 3 in Equation 2 gives the following relationship:

$$\theta_o = \frac{1}{n} \theta_i + \frac{a_1 e^{j(\Omega t + \tan^{-1} K/n\Omega)}}{\sqrt{1 + \left(\frac{K}{n\Omega}\right)^2}} + \frac{a_2 e^{j(n\Omega t + \phi + \tan^{-1} K/n^2\Omega)}}{\sqrt{1 + \left(\frac{K}{n^2\Omega}\right)^2}} \quad (4)$$

If the gain K is high enough, the amplitude of the second and third terms on the right-hand side of

Equation 4 will die out; this will yield the following:

$$\theta_o = \frac{1}{n} \theta_i \quad (5)$$

The actual servo-controlled gear-hobbing machine is shown in Figure 4. The driving worm wheel in the center was manufactured on an ordinary gear-cutting machine, and therefore contains a certain amount of accumulated pitch error (simulating the worm condition of the master on a standard gear hobber). The master worm wheel at the right-hand end of the work spindle is a spur gear accurately finished on a precision gear-grinding machine. The error sensing device—shown near the rim of the master worm wheel—is an electronic capacitive micrometer.

Figure 5 shows the quality of the gears that can be obtained by using this machine. With the controller disconnected, the maximum accumulated circular pitch error of the cut gear was 188 angular sec—actually not too bad for a small hobbed gear. But with the controller in use, the maximum accumulated pitch error was 45 angular sec or 0.009 mm (about 0.00035 in.) on the pitch circle. The master worm wheel used in these experiments was still inaccurate enough so that the effect of its inherent error could be traced on the accuracy curve of gears generated with the controller in use. Further improvement is expected when a more accurate worm wheel is available.

FIG. 4. Experimental gear hobbing machine in Tokyo Institute of Technology laboratory.

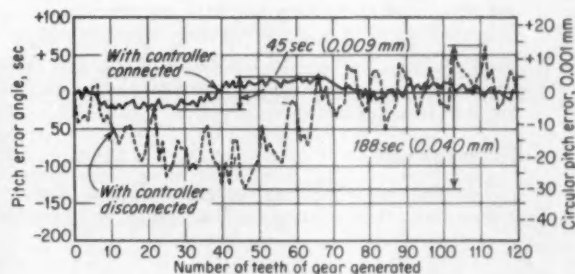
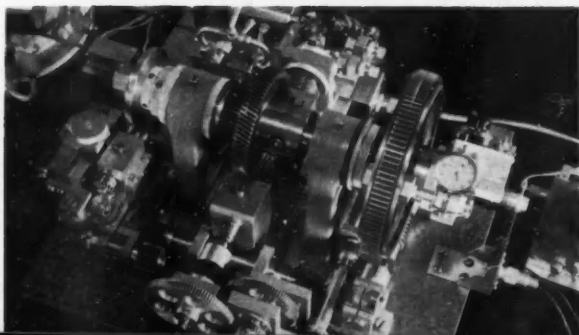


FIG. 5. Machine performance with and without controller connected.

A Survey of Automatic Tank-Level Gages

THE GIST: Remote-reading automatic tank gages should be considered in the same category as other unit instrumentation. In normal refinery process units, instrumentation costs are generally conceded to be about 8 percent of total investment. A complete automatic gaging system for most refineries and many chemical plants can be installed for less than 2 percent of investment. Modification of existing tankage to automatic level readings can be justified, too; one refinery reported an immediate 20 percent return by replacing mechanical bob gages with local reading automatic float gages.

Gaging the liquid level of products in tanks is one of the oldest problems of measurement in industry. When products were comparatively inexpensive and their demand small, accurate measurement was not necessary. In many present-day applications measurement accuracy is still not too important, though other benefits of automatic tank gages (Ref. 1) may justify their use. Where the value of products is high and where products are frequently transferred into and out of tanks, high accuracy and resolution of tank level is important. For example, in a large storage tank having a diameter of 150 ft—common in the petroleum industry—an error of $\frac{1}{4}$ in. in gaging product level represents 5,500 gal of product. Such an error can be significant to either buyer or seller, but it is about the best accuracy that can be obtained by routine manual gaging. Tests on electronic-type automatic tank gages, see box, proved that these gages are generally accurate to $\frac{1}{4}$ in. Use of automatic gages results in greater veracity in shipment billings.

Many principles exist for measuring liquid level, and some of these have been incorporated in a variety of automatic tank gages. Commercially available tank gages vary widely in cost, accuracy, operating principle, method of indicating level, and type of application. Some tank gages now on the market are listed in the tables.

Float-operated

The float-actuated gage measures liquid level as a function of the height of a "ball" or cylinder

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floating on the liquid's surface. The float mechanically drives a counterbalanced, calibrated tape past a fixed reference point; or a noncalibrated tape or cable drives a local dial indicator or counter. For remote reading, the tape also operates an electrical transmitter at each tank, with one receiver accepting signals from many tanks.

Float gages are the most common type of automatic tank gage in use at the present time. Their main features are simplicity of operation, low cost, continuous readings, and, for the mechanical type, no need for an outside source of power. A change in liquid specific gravity due to a change in temperature can introduce errors, but these can be eliminated by making a correction based on the liquid temperature. Table I lists some commercially available float-operated tank gages.

Pressure transmission

The pressure exerted by the weight of liquid, or hydrostatic head, above some reference point is another common determinant of liquid level. The hydrostatic head exerts a force equally in all directions and is independent of liquid volume or vessel shape. The relationship is:

$$H = P/D$$

where: H = height of liquid

P = pressure due to hydrostatic head

D = liquid density

Temperature changes large enough to alter liquid density will appreciably affect measurement accuracy, but correction can be made.

The simplest automatic level gage employing static pressure measurement (the pressure imposed on the liquid's surface remains at or near atmospheric) is the conventional pressure gage or manometer. Here the weight of the liquid acting directly on the gage mechanism gives a measurement of liquid level, Figure 1.

When a pressure greater than atmospheric is imposed on the liquid surface, as in a closed vessel, it adds to the pressure due to the hydrostatic head. To eliminate this source of error, the pressure in the vapor space above the liquid must be canceled from the total pressure. Error cancellation can be accomplished with a U-tube manometer, or a differential converter, Figure 2. One leg, at the tank bottom, measures the pressure due to the liquid and

to the pressure in the vapor space, and another leg measures the pressure in the vapor space. Subtracting the latter pressure from that in the first leg gives a level measurement based on the absolute pressure due to the liquid height in the tank.

Vapors may often condense in the vapor-space leg, and the gradual build-up of the condensed fluid will lead to erroneous level readings. This difficulty is overcome in some installations of differential-converter level gages by purposely filling the vapor-space leg with a fluid of constant head. The constant head is applied to the top of the diaphragm in the differential converter, while its equivalent hydrostatic head is balanced out by an adjustable tension spring on the free end of a pivoted weigh beam. The total head then is applied to the lower side of the diaphragm, and the differential pressure is a true measure of tank level. Several companies (Table II) make gages of the type just described.

Another way to measure hydrostatic head, and hence liquid level, is to use the pressure-bubbling method in conjunction with static and differential pressure gages. An installation of this type of tank gage is shown in Figure 3. An air supply goes to a dip leg connected to the tank at the minimum expected level of liquid. If the air pressure were increased manually at a slow rate, bubbles would not appear until the air pressure equaled the pressure due to the hydrostatic head of the measured liquid. Once the bubbles appear, the air pressure in the dip tube remains constant, since any attempt to increase this pressure would merely result in an increase in air flow. The air pressure in the dip tube, after the appearance of bubbles, is thus a measure of liquid level.

In an automatic pressure-bubbling system, a simple air-flow regulator maintains a small constant flow of air through the dip tube and liquid at the pressure corresponding to the height of the liquid. The air pressure again can be sent to the conventional

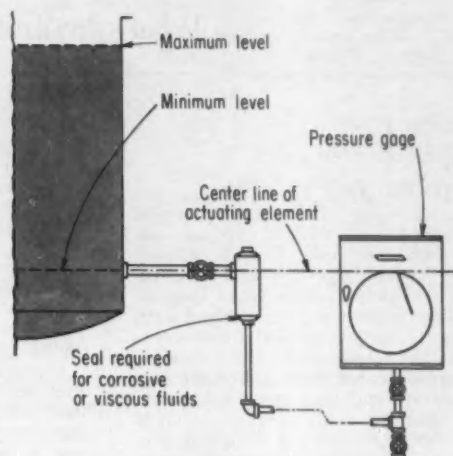


FIG. 1. Simple level gage. Pressure indicates liquid height.

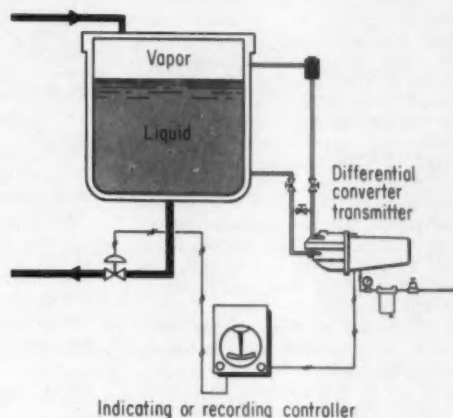


FIG. 2. Differential converter subtracts pressure due to vapor to give true reading of liquid level.

TESTS PROVE ELECTRONIC TANK GAGING MORE ACCURATE

During 1952, when automatic electronic tank gaging systems were first installed on a number of tanks at the Esso Standard Oil Co.'s Bayway (N. J.) Refinery, the company's Committee on Measurement Procedure requested that a program be undertaken to determine whether these gages were more accurate than routine manual gaging. The program was divided into several phases, two of which were:

► Phase 1—to establish a comparison between automatic gaging and carefully-controlled (referee) hand-gaging, using a calibrated steel tape carefully lowered into the tank.

► Phase 2—to compare routine hand-gaging with reference hand-gaging.

In carrying out Phase 1, three referee gagers from the Esso Research

Co.'s Standard Inspection Labs. took daily liquid-level hand gagings on one gasoline-blending tank. While each referee gager took readings on alternate days, readings were simultaneously taken with the automatic tank gage. This procedure was followed for several months, until 114 sets of data had been obtained. A statistical analysis of the data showed the automatic electronic tank gage to be accurate (compared with the assumed 100-percent accurate referee readings) to within $\frac{1}{8}$ in. or better.

Phase 2 consisted of comparing routine liquid-level readings taken by plant personnel with the readings taken by referee hand-gagers. Readings were obtained on 53 tanks. Statistically analyzed, the data showed a routine gag-

ing accuracy of only $\frac{1}{4}$ in., again with the assumption that the referee gaging was 100 percent accurate.

The significance of the above tests is that routine hand-gaging more often than not will be in error by an amount greater than the accuracies claimed for automatic electronic tank gages. Thus, it is misleading to compute the accuracy of an automatic tank gage using routine hand-gaging as a reference. To do so will place on the automatic gage the burden for all error incurred by hand-gaging. Duplicate gagings, taken on more than 200 tanks once a month for a year, showed that on tanks where large discrepancies occurred between hand-gaging and automatic gaging, a recheck proved the automatic gage correct in over 98 percent of the cases.

What's Available in Automatic Tank Gages

Table I

Float-operated gages

SHAND AND JURS CO. Liquid Level Gage (2006)—features digital readout, \$170; ST-8000 gage uses calibrated tape read through window, \$152. Both gages give local indication at ground level. High Speed Telepulse allows selective remote reading of gages; uses electromechanical transmitters coupled to gage heads. Index wheels in transmitter are positioned by the gage and are read by a sweep mechanism. Transmitter sends pulses proportional to level over wire pair or equivalent in radio, microwave, etc., circuits. Temperature and pressure may be handled similarly. Transmitters cost \$220 each. Cost of 20-point level receiver is \$630. Additional capacity available at \$100 per group of 20 points. (Berkeley, Calif.)

A. O. SMITH CORP. Tank gage has dial driven by stainless-steel cable connected to float. Reading is at tank at ground level. \$200. Can be equipped for remote indication. (Los Angeles, Calif.)

THE TOKHEIM CO. Float Gauge has graduated tape viewed through a sight glass at eye level. Gauge is pressure tight. Not recommended for remote indication. (Cedar Rapids, Iowa)

THE LIQUIDOMETER CORP. Liquidometer utilizes float and hydraulic pressure principles; float travel is linked to bellows and resulting pressure transmitted to a bellows indicator or recorder via completely filled capillary tubes. With dial indicator, from \$146 to \$209, depending on dial size. Recording unit, \$355. (Long Island City, N. Y.)

THE VAPOR RECOVERY SYSTEMS CO. Makes several types of Varec No. 2500 Series Tank Gauges. All have a float-actuated, perforated tape driving counter-indicators graduated in feet, inches, and $\frac{1}{8}$ inches. The Electronic Gauger is a potentiometer-analog system using dc voltage as the transmission means and is suitable for distances up to approximately one mile. The Varec Pulse Code System provides digital readout and/or printing and uses pulse code transmission between the tanks and the receiver. This system can be used for unlimited distances and can also include the telemetering of other variables such as temperature, pressure, etc. (Compton, Calif.)

Table II

Pressure-transmission gages

THE LIQUIDOMETER CORP. Levelometer indicates static hydrostatic head of stored liquid, using air bub-

bling method. Like Liquidometers, Levelometers have calculated accuracy within 2 percent of full scale, with better accuracy attainable by liquid calibration. \$31 to \$172, depending on dial size. (Long Island City, N. Y.)

MINNEAPOLIS - HONEYWELL REGULATOR CO. Tank gage is an adaptation of M-H's pressure controller. Accuracy on large tanks is about 5 percent of liquid level. Approx. \$175. (Philadelphia, Pa.)

Several companies make manometer level gages, all operating in about the same manner. Air or another gas is needed for pressure bubbling. Reading can be transmitted to approximately 100 ft from the tank. Cost varies from \$85 to \$125 per manometer. Some makers are: **King Engineering Co.** (Ann Arbor, Mich.); **Asch Equipment Co.** (Forest Hills, N. Y.); and **The Meriam Instrument Co.** (Cleveland).

Differential converter tank gages, described in the text, are also made by many companies, but details may vary. The cost of the gage itself ranges from \$300 to \$400, plus \$100 to \$150 for a recorder. Accuracy is about 2 to 3 percent of the liquid level. An air source is needed when used with the pressure-bubbling method. Some makers are: **The Foxboro Co.** (Foxboro, Mass.); **Fischer & Porter** (Hatboro, Pa.); **Mason-Neilan** (Norwood, Mass.); **Minneapolis-Honeywell Regulator Co.** (Philadelphia, Pa.); **Moore Products Co.** (Philadelphia, Pa.); and **Taylor Instrument Cos.** (Rochester, N. Y.).

Table III

Electronic gages

AUTOMATIC TIMING & CONTROLS, INC. Tank gage uses a dial or graduated tape for local indication. A detecting unit is lowered from tank top by a cable until a small float touches the liquid surface and stops the motor. \$750 per gage plus \$1,800 for multi-tank receiver for remote indication. (King of Prussia, Pa.)

RAMSEY ENGINEERING CO. Gage has a mechanical-counter indicator. Completes an electric circuit the instant a descending weighted bob contacts the liquid's surface. The bob is normally at rest at the tank top, with readout on demand. Recommended for use only on nonflammable, electrically conductive liquids. \$1,000 to \$2,500, depending on application. (St. Paul 13, Minn.)

ROBERTSHAW - FULTON CONTROLS CO. Makes a capacitance-level gage, as described in the text. There are no moving parts and the readings can be transmitted up to one mile. Accuracy is 2 percent on tanks up to 30 ft tall. \$700 in explosion-

proof housing, \$400 in vapor-tight case. (Anaheim, Calif.)

INSTRUMENTS, INC. Also makes a continuous-reading capacitance-level gage, as described in the text. The meter is calibrated in units of level. \$400 in vapor-tight case. (Tulsa, Okla.)

GILBERT & BARKER MFG. CO. Makes the Gilbarco electronic tank gage. A sensing element suspended over the liquid transmits rf signals. A comparison of detected and fixed signals raises or lowers the sensor as level changes. Uses three vacuum tubes. Accuracy is within $\frac{1}{8}$ in., not affected by specific gravity variations. Excellent field test data. Uses Weston averaging resistance thermometer to correct for temperature variations. \$995 per transmitter, plus \$1,225 for basic (non-explosion-proof) 24-tank receiver. (West Springfield, Mass.)

BOGUE ELECTRIC CO. Makes a sonic gage having meter or digital display of level. Sonic pulses are transmitted from a transducer at the tank bottom. Timing of initiation and receipt of pulse echo is translated into liquid level. \$545 and up. (Paterson, N. J.)

ACOUSTICA ASSOCIATES, INC. Ultrasonic Continuous Level Gages measure weight, volume, or level of any liquid by timing the travel of ultrasonic pulses. Digital or analog readout. Prices vary with application. Mineola, N. Y.)

UNITED ENGINEERS, INC. Makes a level gage employing a radium source located in a float. A gamma ray detector is located on the top of the tank, and the amount of detected radiation, inversely proportional to the square of the distance between the source and detector, indicates the liquid level on a recorder, \$650. (Tulsa, Okla.)

THE OHMART CORP. Makes the radiation gage described in the text. Level is shown on an indicator or recorder. Uses single-point sources or a continuous strip source, depending upon range requirements. Price \$1,000 and up, depending upon range and precision. (Cincinnati, Ohio)

RADIATION COUNTER LABS. Makes a predetermined level gage (Model 40105) using a small radiation source inside or outside a tank, with a scintillation detector outside the tank in the same horizontal line with the desired level. Suitable for coke storage tanks, molten glass furnaces, oil and dairy product tanks, etc. The continuous liquid level gage (Model 40104) uses a radioactive source enclosed in a float which follows liquid level. Guides inside tank give desired linearity. Applications are for sanitary measurements of milk and brewery products, and for measurement of natural gas in underground storage cavities. (Skokie, Ill.)

types of pneumatic receivers calibrated in units of level. The air-supply pressure must be greater than the pressure equivalent to the maximum expected liquid level. One advantage of the pressure-bubbling method over direct measurement is that corrosive liquids do not come in contact with the instruments themselves—air and not liquid enters the gage.

Electronic methods

Several electronic methods are used for gaging tank liquid level, including the measurement of capacitance, sonar pulses, radiation, and contact and radio-frequency sensing of the surface, Table III.

In the capacitance method (Ref. 2) an electrode, serving as one plate of a capacitor, is installed vertically in the tank. The tank wall serves as the other capacitor plate. Capacitance thus becomes a function of the design geometry, the dielectric constant of the materials between the plates (air and liquid to be measured), and the height of the liquid. In practice, since the first two functions are relatively constant, capacitance depends on liquid level, so that a measure of capacitance is a measure of level. Measurement of capacitance is usually accomplished by an inductance-capacitance bridge. The meter in the bridge can be calibrated in units applicable to the size of tank being gaged.

One type of surface-sensing gage works by completing an electric circuit the instant a descending bob contacts the surface of the liquid. The bob is normally at rest at the tank top, and descends—on demand for readout—to the surface. The tape holding the bob is connected to a mechanical counter calibrated in feet and inches. This type of gage is limited in use to nonflammable and electrically conductive liquids.

Another type of surface-sensing tank gage has this unique feature: only a wire tip contacts the liquid being measured. The sensing element is a hollow metal cylinder from which a straight wire antenna radiating radio-frequency energy projects downward 11/16 in. below the open end of the cylinder. The antenna tip penetrates the liquid approximately 1/16 in. and is maintained there, as the level rises and falls in the tank, by a servo system.

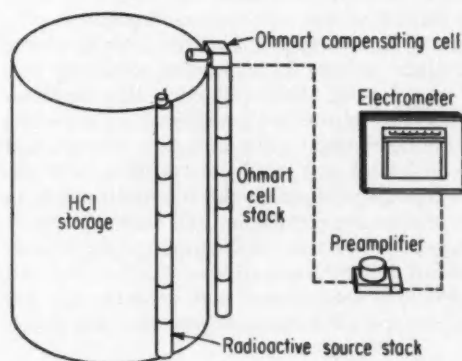


FIG. 4. Radioactive source and detectors mounted across chord of tank measures level without contacting fluid.

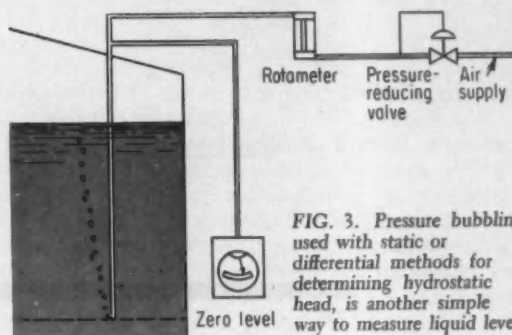


FIG. 3. Pressure bubbling used with static or differential methods for determining hydrostatic head, is another simple way to measure liquid level.

A fixed bias signal—a continual "up" signal—is applied to the sensing-element drive motor. If the sensing element is not near the liquid surface the gage generates a "down" signal that overrides the bias. As the sensing element drops, the probe tip penetrates the liquid surface, detuning the oscillator. The resulting energy loss reduces the antenna signal level until the fixed bias equals the antenna level, at which condition the drive motor stops. When the level rises, the antenna signal drops further, permitting the "up" signal to take over and raise the probe until the antenna and fixed bias signals are again equal. The motor raises and lowers the sensing element by means of a perforated steel tape.

The radiation method of gaging liquid level works by measuring the absorption of gamma rays penetrating the liquid. An installation is shown in Figure 4. Here a stack of radioactive sources, commonly cobalt 60, is mounted outside the tank and the detector is mounted across a chord. The radiation passes through the tank and is detected by a Geiger counter, scintillation detector, or other type of detector, whose output goes through a preamplifier to a highly sensitive electrometer calibrated in units of level. Once the design parameters are fixed, the radiation received by the detector decreases as level increases. A feature of this gaging method is that the instruments do not contact the liquid.

In sonar tank gages, pulsed sonic vibrations are transmitted from a transducer at the tank bottom to the surface of the liquid, where they are reflected to a receiver and converted to electrical impulses. The time between pulse transmission and receipt of the echo is a measure of the liquid level. Except for experimental models, there are no known sonic tank gages in every-day industrial use capable of measuring level in tanks taller than 20 ft. In the experimental model tested the electronic unit contained 68 vacuum tubes. The receiver was located in the control house. No local reading was available at the tank.

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1. CENTRALIZING TANK FARM OPERATIONS WITH ELECTRONIC LEVEL GAGES, Howard S. Andrews, "Control Engineering", December 1958, p. 86.
2. USE CAPACITANCE FOR ACCURATE LEVEL MEASUREMENT, F. W. Hannula, "Control Engineering", November 1957, p. 104.

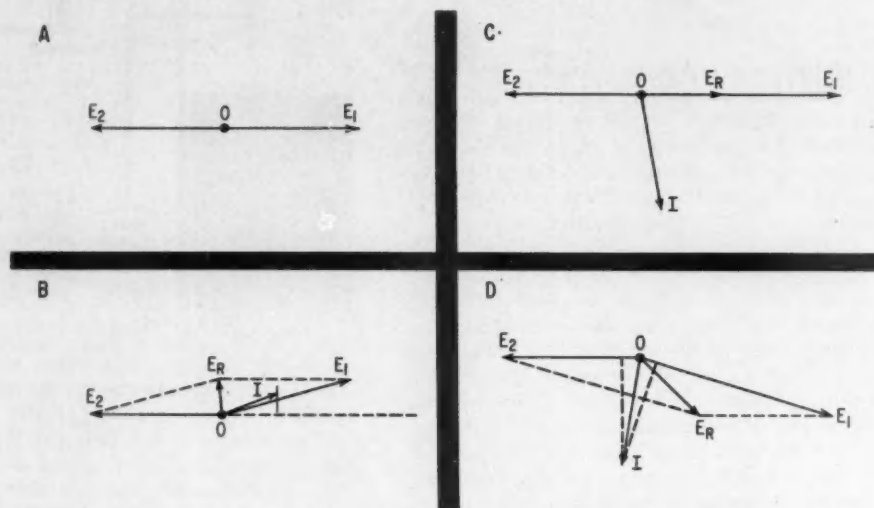


FIG 1. Vector diagrams of induced secondary voltages and loop currents for identical (A, B) and nonidentical (C, D) tie motors.

Fundamentals of Tie-Motor Control—II

Their high synchronizing torques continue to make polyphase-excited units most desirable for synchro ties. Although initially considered a serious drawback, their asymmetrical performance characteristics are now understood and can be counteracted by unique circuit designs. Here the author describes some of the latter, including a system that holds synchronism **during acceleration and braking**, and also a double synchro tie offering high stability in reversible drives.

A. H. MYLES
Square D Co., EC&M Division

In the first part of this article (CtE, Jan., p. 89) it was stated that the asymmetrical characteristics of polyphase-excited tie motors are due to the action of two different torques. The first of these is a normal polyphase induction-motor torque produced by rotor losses, which always acts in the direction of field rotation. The second is the synchronizing or tie torque, which acts either with the field or against it, depending on direction of displacement.

The origin of the synchronizing torque can best be traced by considering first the operation of transmitter and receiver units that are identical. When both rotors are in coincidence, the secondary voltages are equal and opposite, Figure 1A. And, because there is no secondary current, the torque is zero. When the rotors are not aligned, secondary voltages, E_1 and E_2 , are equal but are displaced in phase. The resultant voltage E_R sets up a circulating current I (lagging by almost 90 deg) that transfers energy between transmitter and receiver. The motoring torque developed by the receiver is proportional to the component of I 180 deg out of phase with E_2 and the retarding torque on the transmitter shaft is proportional to the component of I that is in phase with E_1 . Both motoring and retarding torques may be classified as synchronizing torques.

Nonidentical transmitters and receivers can be used in synchro-tie systems despite the probability

that their induced secondary voltages will be unequal. Figure 1C shows the induced voltage vectors for two dissimilar units whose rotors are in space phase. These voltages are opposite but not equal, so that there is a resultant voltage available, which sets up a circulating current. This current I lags E_R by nearly 90 deg and has components in phase with E_1 and 180 deg out of phase with E_2 . These components of current establish synchronizing torques that tend to advance the receiver position and retard the transmitter motion. Thus, E_1 moves in a lagging direction and E_2 in a leading direction until the components of I on E_1 and E_2 are both positive and of sufficient value to achieve the following:

$$I'E_1 = I'E_2$$

where I' = component of I on E_1

I'' = component of I on E_2

When this equality is reached, Figure 1D, the transmitter and receiver will be in synchronism—although their synchronous positions will be displaced from one another.

The resistance of the leads between transmitter and receiver is also a critical factor when polyphase excitation is used. High resistance leads not only reduce the induced rotor current but decrease the lagging angle between the induced voltage and current, causing a detrimental effect on the component producing the synchronizing torque.

Slow-speed applications

Polyphase excitation is especially suitable for applications involving slow speeds and power loads. Where a high friction load is placed on the receiver (as is the case in most conveyor drives, for example), the greater amount of receiver torque available by adopting polyphase excitation and by operating the system in the direction of field rotation will easily warrant the use of the additional equipment involved. In applications of this nature, the driving motor is usually much larger than the tie motors and often no endeavor is made to select two identical motors. However, if the receiver load has high inertia, the tie motors should operate against the direction of field rotation because any rapid decrease of speed of the driving motors causes the transmitter and receiver to interchange their functions. The tie torque will then be of a maximum value during these periods.

The starting routine for polyphase units operating with polyphase excitation begins with the application of single-phase power to two windings of the transmitter and receiver fields. After a time delay sufficient for the units to pull into step, the third windings are energized. Next, power is applied to the driving motor and the entire system accelerates to running speed. The elementary wiring diagram, Figure 2, shows the necessary connections. If the installation so requires, the receiver can operate in the reverse direction with respect to the transmitter. However, this reversal cannot be accomplished by simply interchanging two stator leads as in the case

of an induction motor. It is necessary to reverse the two rotor leads as well.

Because polyphase synchro-tie systems often involve large machines supplied from mains of high capacity, the control engineer must furnish some form of overload protection. The driving-motor overload devices can be made to protect the entire system, provided that the driving motor and tie motors are of comparative size and that there is no danger of the tie motors being pulled out of step. When tie motors are forced out of synchronism, high tie-motor currents can exist despite the fact that there is little torque developed and, consequently, little load reflected on the driving motor. Under these conditions, the tie motors must be given separate protection. Because rotor current is a truer indication of load increase than is primary current, it is advisable to place the tie-motor overload relays in the secondary circuit. Further, these relays should be of the thermal type. A magnetic overload relay has a tendency to reset between the current peaks in the fluctuating current produced by an out-of-step condition. The overload relays located in the secondary circuit give no protection against short circuits or grounds. Hence, an instantaneous-trip overcurrent device should also be placed in the line supply to the transmitter and receiver.

High-speed applications

The third major class of tie-motor applications covers either light or power loads operating at high speeds. In this group, the speed range extends up to the maximum speed allowable from the standpoints of induced rotor voltage and mechanical strength. At such levels, the speed approaches and often surpasses the synchronous speed of the tie motors. It

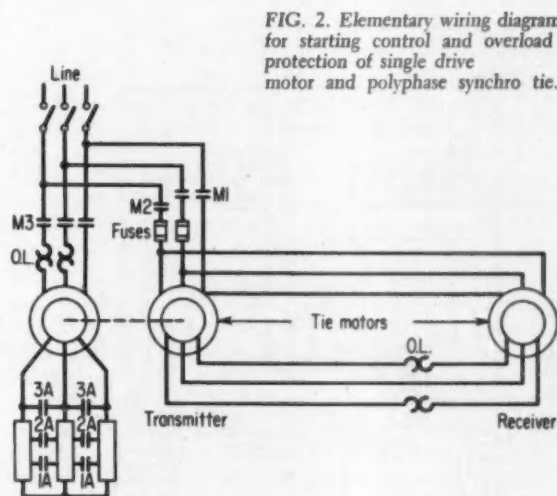


FIG. 2. Elementary wiring diagram for starting control and overload protection of single drive motor and polyphase synchro tie.

then becomes necessary to operate against the rotation of the magnetic field, as apparent from the polyphase speed-torque curves (Figure 9B—Part I). In reversing drives some means must be provided for reversing the direction of rotation of the tie-motor fields. Another feature of many applications in this group (hoist and crane drives, for example) is that both tie-motors are coupled to drive motors. Thus, either unit may function as transmitter or receiver, depending on the load conditions at any particular time. The general technique is illustrated by Figure 3, an elementary wiring diagram of two hoist motors, each connected directly to a tie motor. The tie motors act to synchronize the hoist motors to prevent one end of the drive from getting ahead of the other.

In this type of control it is desirable to arrange the switching so that the entire drive will not become inoperative should any motor fail. Thus, the circuit is designed so that the two drive motors may be operated without the tie loop by opening the five-pole switch. And either main motor may be isolated by opening its corresponding disconnect switch.

Under normal operation, moving the master to "hoist" or "lower" closes the corresponding directional contactors (*H* and *L*). Simultaneously, contactors *M*, *P*, and *B* are energized to apply three-phase power to all motors and release both electrical brakes. Initially the four motors are stalled because the tie motors are functioning as induction motors also, with field rotation and induction-motor torque acting in opposition to the driving motors. However, the three-phase tie motors have the additional torques that tend to give positive synchronization, regardless of the extent of the initial out-of-step condition. Thus, either or both transmitter or receiver will move to change the displacement error and cause synchronization. After the tie motors pull into step,

contactor *P* opens to remove the induction-motor effect of the tie motors. Then, the drive motors start and accelerate in the conventional manner.

Bringing this type of drive to rest with both drive-motor shafts in position correspondence may be more of a problem than synchronized acceleration. Simply removing power from the driving motors and setting the motor brakes is not the answer because any difference in brake adjustment, brake friction, or brake-setting time will cause one end of the drive to stop ahead of the other. However, if the two drive motors are brought to rest before the brakes are set, the tie motors (kept energized) can easily maintain synchronism. This can be accomplished by connecting the common secondary resistance across the tie-motor secondary leads. The resistance value is chosen so that the tie motors have an induction motor torque slightly greater than that of the drive motors with all secondary resistance inserted. This creates a situation wherein each tie motor is bucking its corresponding drive motor while the three-phase tie torque is maintained. The bucking torques of the tie motors bring the load to rest, at which time the brakes are set and power removed from all motors.

The origin of the negative or braking torque is easily explained with reference to two polyphase motors mechanically coupled together and with their magnetic fields rotating in opposite directions. If secondary resistance is added to both motor rotors, the maximum or pullout torques can be made to occur at a negative speed (curves 1 and 2 in Figure 5.) At standstill the two motors develop torques that are of equal magnitude but act in opposite directions. The coupled motors are, thus, stalled. If the system is rotating in either direction, the motor operating against its field develops the greater torque. The resultant torque difference produces a braking action that is directly proportional to speed.

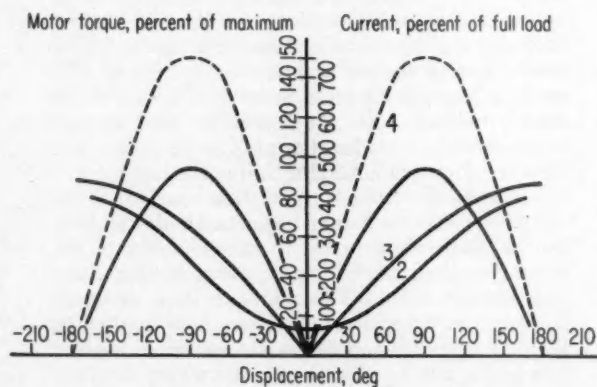
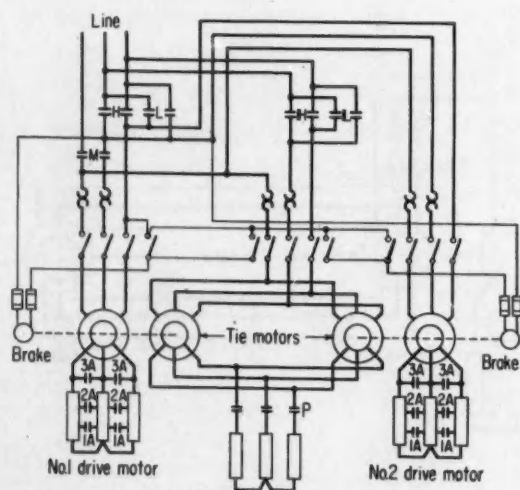


FIG. 4. Torque characteristics for two polyphase motors whose magnetic fields rotate in opposite directions.

FIG. 3. Control circuit for synchronizing two hoist motors during acceleration, normal operation, and stopping.

FIG. 5. Current and torque relationships as a function of speed in polyphase double tie-motor system. Curves 1 and 4 relate to the torque characteristics with and without secondary resistance. Curves 2 and 3 relate to primary and secondary current, respectively.

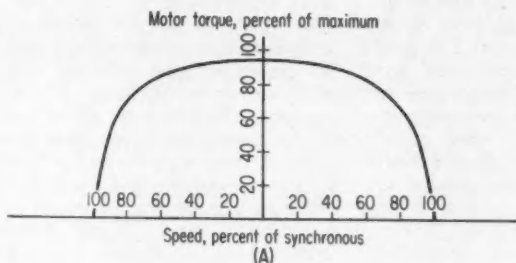
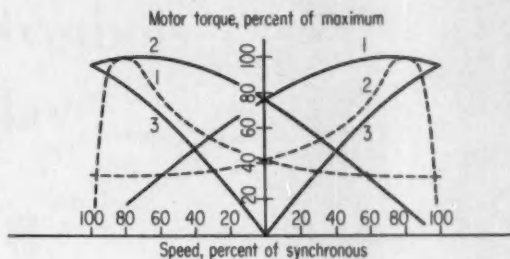


FIG. 6. Symmetrical torque-displacement characteristic for a double synchro tie.

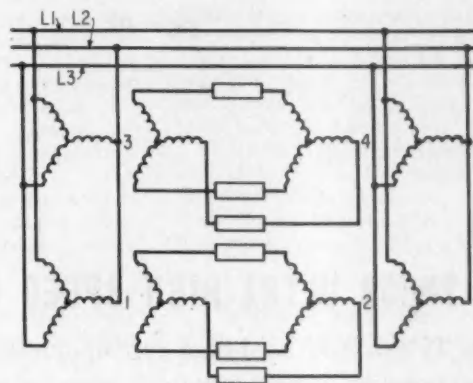


FIG. 7. Double tie motor connections showing resistance added to secondary leads.

Stable drives

The fourth classification of tie motor applications covers special drives that must not become unstable. One example of such usage is shipboard steering gear. This application usually requires the provision of torque to some mechanism for controlling rudder position. The conventional system of polyphase tie-motor drive is unsuitable because, should the helmsman continue to turn the transmitter when the rudder is hard over, the units would be pulled out of synchronism. In addition, the wheel would tend to be driven at induction motor speed. Furthermore, single-phase tie motors would also be unstable in this application if they were pulled out of synchronism at a speed sufficient for induction motor operation.

A scheme that has proved most successful for highly stable drives involves the use of double tie-motor units. The double-tie motor system consists essentially of two standard tie-motor loops with their transmitter rotors either coupled together or assembled on a common shaft. The receiving unit is a duplicate of the transmitter. The double-tie motors have two distinct advantages: (1) symmetrical torque-displacement or torque-speed characteristics, Figures 5 and 6; and (2) the development of negative or braking torque when forced out of synchronism.

Figure 7 shows a connection diagram for a double

tie-motor system. Units 1 and 2 make up one transmitter and receiver system, and units 3 and 4 are combined in the second system. Units 1 and 3 are coupled together, as are units 2 and 4. The direction of field rotation for units 1 and 2 is opposite to that for units 3 and 4. With this method of assembly and connection, the resultant tie torque for rotor displacement will be symmetrical for both directions of rotation.

If there is no resistance in the interconnecting secondary leads and the transmitter and receiver are forced out of synchronism while rotating, a resultant induction motor torque will exist in the direction of rotation. This is shown by the dashed curves in Figure 5. Now consider what occurs if resistance is added to the secondary interconnecting leads, Figure 7, and the transmitter and receiver are forced out of synchronism. As previously explained, the net or resultant torque can be made to be negative and a braking action will result. Therefore, if the units are forced out of synchronism at any speed whatever, they will not motor but will come to rest immediately. Since double tie-motor units have symmetrical torque characteristics, they are controlled in a manner similar to tie motors operated with single-phase excitation. If it is necessary to reverse the direction of rotation of the receiver with respect to the transmitter, the two stator and two rotor leads of each receiver unit are reversed.



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CHARACTERISTICS†	Conditions	Sym	Min	Max	Units	MAXIMUM RATINGS						
Emitter Breakdown Voltage	$I_E = -100 \mu\text{A}$ $I_C = 0$	BV_{EBO}	-3.5	—	Vdc	V_{CB}^*	V_{EB}^*	V_{CE}^*	T_{STG}	I_E	I_C	T_J^\ddagger
Collector Breakdown Voltage	$I_C = -100 \mu\text{A}$ $I_E = 0$	BV_{CBO}	-15.0	—	Vdc	Vdc	Vdc	Vdc	°C	mAdc	mAdc	°C
Static Forward—Current Transfer Ratio	$I_C = -10 \text{ mAdc}$ $V_{CE} = -0.3 \text{ Vdc}$	h_{FE}	25	—	—	-15	-3.5	-15	-65 to +100	50	-50	100
Base Voltage	$I_C = -10 \text{ mAdc}$ $I_B = -0.4 \text{ mAdc}$	V_{BE}	0.34	0.44	Vdc	* These voltages may be exceeded (without permanently impairing the transistor) provided the current is limited to 100 μA .						
Collector Cut-Off Current	$V_{CB} = -4.5 \text{ Vdc}$ $T_{\text{ambient}} = 65^\circ\text{C}$	I_{CBO}	—	-50	μAdc							
Delay and Rise Time	$V_{BE}(0) = -0.5 \text{ Vdc}$ $I_B(1) = -1.0 \text{ mAdc}$ $V_{CC} = -3.5 \text{ Vdc}$ $R_L = 300 \text{ ohms}$	$(t_d + t_r)$	—	75	μsec	† Derate at 0.5°C/mw. This is equivalent to a maximum power rating of 150 mw at 25°C ambient.						
Storage Time	$I_B(1) = -1 \text{ mAdc}$ $I_B(2) = -0.25 \text{ mAdc}$ $V_{CC} = -3.5 \text{ Vdc}$ $R_L = 300 \text{ ohms}$	t_s	—	100	μsec							
Fall Time	$I_B(1) = -1 \text{ mAdc}$ $I_B(2) = -0.25 \text{ mAdc}$ $V_{CC} = -3.5 \text{ Vdc}$ $R_L = 300 \text{ ohms}$	t_f	—	100	μsec	‡ This specification covers the detail requirements for a transistor having the following characteristics at a case temperature of $25 \pm 3^\circ\text{C}$, unless otherwise specified.						



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Core Matrix Stores Symbols for High-Speed Display

ELMER C. SIMMONS, Laboratory for Electronics, Inc.

The five-by-seven matrix of magnetic cores shown in Figure 1 is used as the source of alphanumeric and other special symbols in a new unit designed to display the output of computers and other data processing systems. The symbols are permanently stored in the matrix as the pattern positions of the cores through which readout wires are threaded. A sector of the face of a cathode-ray tube is then scanned synchronously with the matrix to display the stored symbol.

For each character to be displayed, a readout wire is threaded through the selected cores of the matrix such that the threaded cores form a pattern resembling the character to be produced. Figure 2 illustrates how the numeral "0" is formed in the matrix.

About 150 different characters, which may be arabic numerals, letters in nearly all alphabets, punctuation marks, or special symbols, can be threaded into one matrix. If at any time it is necessary to change one of the characters or add new ones, an output wire can be threaded through the cores in the desired pattern as simply as a child strings beads.

Operation of symbol generator

To illustrate the operation of the matrix, consider all of the cores to be reset. A pulse applied to the "set" windings of column 1 by the column

drivers will set each of its cores. Next, resetting rows A to G sequentially by the row drivers, will induce a pulse in the readout wire for each core in column 1 threaded by the wire. Note that the cores in the other columns in this case will not produce an output voltage since only column 1 was set. Next, pulse column 2 followed by rows A through G again. Repeat for each column in order, to form a pulse train for the particular character.

This operation is equivalent to pulsing the cores sequentially starting with the bottom of column 1, to the top of column 1, then to the bottom of column 2, etc. Synchronized sweep voltages are formed to create a raster in step with the pulsing of the matrix.

Note that all readout wires in the matrix are energized simultaneously for each pulsing operation, but pulses from a particular readout wire are selected and applied to a video amplifier to brighten the raster at the correct points to form the selected character.

The character to be displayed is selected from the core matrix by the input code for the character supplied by the data processor, see Figure 3. This code may be a six-bit code as shown, or more or less, but it must be parallel-by-bit. The decoder is a diode matrix that energizes a single one of n output wires, depending on the input code, where n is the num-

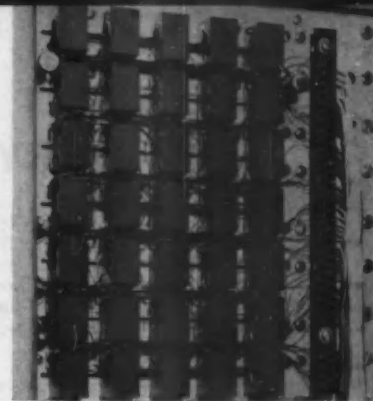


FIG. 1. Five-by-seven matrix of magnetic cores wired for symbol storage.

ber of characters threaded into the core matrix. The decoder also produces a trigger pulse that initiates the core matrix and CRT viewer scans.

The selected wire from the decoder gates the output pulses from the correct readout wire in the core matrix to the video amplifier.

The symbol position control consists of vertical and horizontal step generators that determine, respectively, the position of a line of characters, and a character within a line.

Flexibility in application

The present symbol generator can write 10,000 characters per sec, and it is feasible to increase its speed to 30,000 characters per sec. The CRT used is a display-type storage tube with a P1 phosphor that displays a written character until erased.

This type of character storage has great flexibility. A single symbol generator can drive many remote viewers in parallel for simultaneous display. And, with multiplexing, one symbol generator can drive several viewers for writing several messages simultaneously. Also, the display can be photographed for permanent records.

FIG. 2. Readout wires are threaded through cores in the pattern of the symbol to be generated; "0" is illustrated.

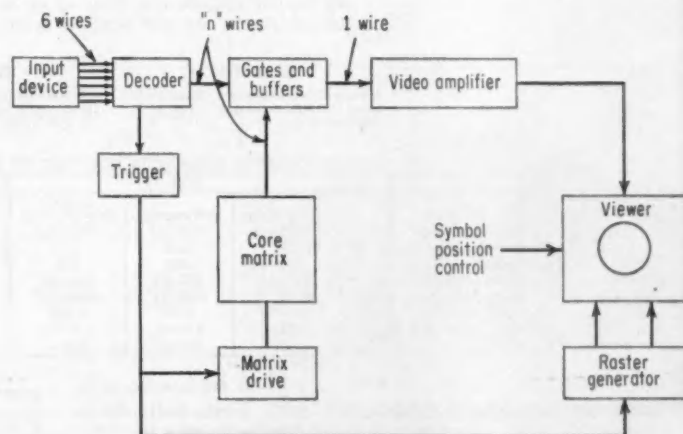
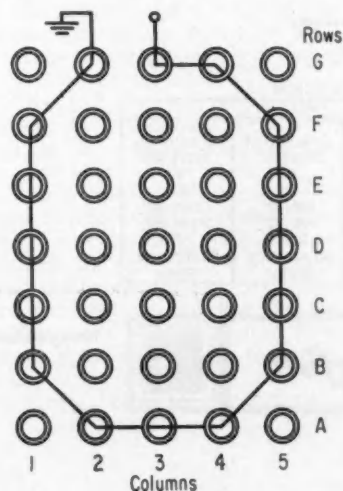
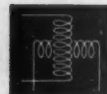


FIG. 3. Coded input from computer selects the correct readout wire from core matrix to display on viewer.

KEARFOTT PRECISION RESOLVERS FOR EVERY SYSTEM APPLICATION



Kearfott has available a complete line of precision resolvers for every system application. Computing resolvers range in functional accuracy from .05% to .005%, in bridge accuracy from 3 minutes to 20 seconds of arc and in size from 11 to 25. Non-compensated resolvers range from 5 minutes to 20

seconds of arc in accuracy, from 8 to 25 in size. All Kearfott resolvers feature stainless housing, shafts and bearings and corrosion-resistant lamination materials for maximum environmental resistance. Optional designs available for operation at 200°C and in environment of 2000 cps vibration at 30 g's.

Computing Resolvers

Available with integral compensating windings. Can be provided with trimming networks to match existing isolation amplifiers or Kearfott-designed transistorized amplifiers.

Size 11

For applications where size and good functional accuracy are of paramount importance. Functional accuracy as good as .05% and bridge errors of 3 minutes of arc are in production.

Size 15

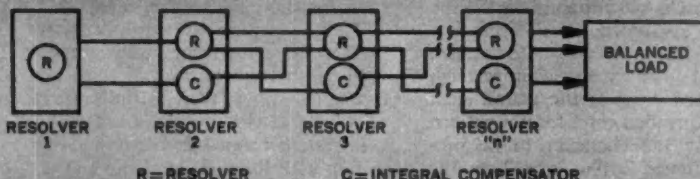
A 2:1 improvement in functional accuracy and bridge error obtained in this configuration. Unit tabulated is the direct equivalent of standard Navy BuOrd Mark 4 Mod 3 and contains necessary trimming network for standard buffer amplifiers. Transformation ratio is 1.000 ± .0001, phase shift 0° ± 1 minute. Functional accuracy of .025% and bridge error of 1.5 minutes of arc are standard.

Size 25

For applications demanding the highest order of accuracy. Close attention has been paid to design parameters.

Size 18

A special resolver which permits a unique cascading of these units without the necessity for buffer amplifiers. Typical application is illustrated in following cascade:



COMPENSATED RESOLVERS FOR PRECISE COMPUTER APPLICATIONS

COMPENSATED RESOLVERS FOR PRECISE COMPUTER APPLICATIONS					
SIZE	11		15	18	25
PART NUMBER	R980-01	R980-41	T980-51	V980-004	425506-1
Excitation Volts—(Max.)	60	60	26	26	25
Frequency—(cps)	400	400	400	400	400
Primary Impedance	629 + j2510	450 + j2200	220 + j1000	3000 + j (0 ± 40)	1630 / 78.5°
Secondary Impedance	695 + j2750	500 + j2300	240 + j1100	3000 + j (0 ± 40)	1620 / 80°
Transformation Ratio (Primary to Secondary)	.980	.980	.980	.775	.980
Transformation Ratio (Compensator to Rotor)	.985	.985	.950	.775	.985
Phase Shift (Lead)	8.5°	7.5°	8.5°	0° ± 10'	1°
Fundamental Null (MV)	15	15	8	15	15
Bridge Error From E.Z. (Max.)	7 mins.	5 mins.	3 mins.	3 mins.	20 Seconds
Primary	Stator	Stator	Stator	Stator	Stator

Non-Compensated Resolvers

Basically for application in precise data transmission systems. These synchro resolvers permit system designer to achieve system errors of better than 1 minute of arc without using 2-speed servos and elaborate electronics. By proper impedance matches up to 64 resolver control transformers can also operate from one resolver transmitter.

Size 11

Where size is important. These units have a maximum unit error of 3 minutes of arc.

Size 25

Where highest accuracy is required. These units have a maximum error as low as 20 seconds of arc.

NON-COMPENSATED RESOLVERS FOR PRECISE DATA TRANSMISSION

	SIZE 11			SIZE 25		
Type Resolver	Transmitter	Differential	Control Transformer	Transmitter	Differential	Control Transformer
Part Number	R982-004	R982-011	R982-012	Z5161-001	Z5191-001	Z5151-003
Excitation Volts (Max.)	26	11.8	11.8	115	90	90
Frequency (cps)	400	400	400	400	400	400
Primary Impedance	170 / 77°	850 / 80°	2000 / 80°	400 / 80°	800 / 80°	8500 / 80°
Secondary Impedance	42 / 80.5°	1000 / 79°	8000 / 76°	260 / 80°	900 / 80°	14000 / 80°
Transformation Ratio	.454	1.000	1.906	.7826	1.000	1.278
Max. Error from E.Z.	3 mins.	3 mins.	3 mins.	20 seconds	20 seconds	20 seconds
Primary	Rotor	Stator	Stator	Rotor	Stator	Stator

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Two Ways to Use The Pot and The Pendulum

1. To Replace Vertical Gyros in Torpedoes

BERNARD LEVINE

KeTay Dept., Norden Div. of
United Aircraft Corp.

Many systems now using a vertical gyroscope for a position reference could possibly operate just as well if a potentiometer actuated by a damped pendulum were specified instead of the gyro. The limitations are sensitivity and response to accelerations other than gravity.

A typical successful application of a pendulum-actuated potentiometer to replace a vertical gyro is shown in Figure 1. Here the pendulum potentiometer is used as the pitch angle reference in a torpedo. Note that this is a true feedback system in which the comparison of the reference (true vertical) with the controlled variable (pitch angle) is made entirely within the potentiometer.

The amplifier in Figure 1 is necessary to supply the rather substantial forces needed to control a torpedo's stabilizer fins, as well as to make maximum use of the potentiometer's sensitivity. If less than maximum sensitivity is sufficient, the pendulum could control enough power directly to handle light loads—up to 20 watts in a 3-in. unit.

The sensitivity of a pendulum potentiometer can be controlled by:

- the resolution of the winding (turns per deg)
- the friction force of the wipers on the winding and the slip ring
- the weight of the pendulous mass
- the length of the pendulum

The component of the mass that does all the work is the mass times the sine of the angle (measured from vertical) through which it is rotated. This component must be greater than the frictional forces before the unit will operate. The frictional forces must, therefore, be kept to a minimum and the pendulous mass to a maximum. Reducing the length of

the pendulum increases the response.

Pendulum potentiometers are available, Figure 2, which have sensitivities as high as 4 min of arc in a 3-in. diameter case. These use tungsten as the pendulous mass.

The sensitivity of the pendulum potentiometer to transient horizontal accelerations can be minimized by damping the pendulum. This is done in available units by filling the entire potentiometer case with a silicone damping fluid. The exact degree of damping can be controlled for particular applications by varying the

viscosity of the silicone fluid. Damping, of course, reduces the response to a true change of vertical.

The pendulum potentiometer may be useless as a vertical reference in applications where sustained horizontal accelerations occur, such as the centripetal accelerations resulting from changes in direction in aircraft. But this limitation suggests its possible usefulness as an accelerometer in outer space. A 360-deg potentiometer element could be used in such an application in place of the sector shown in Figure 2.

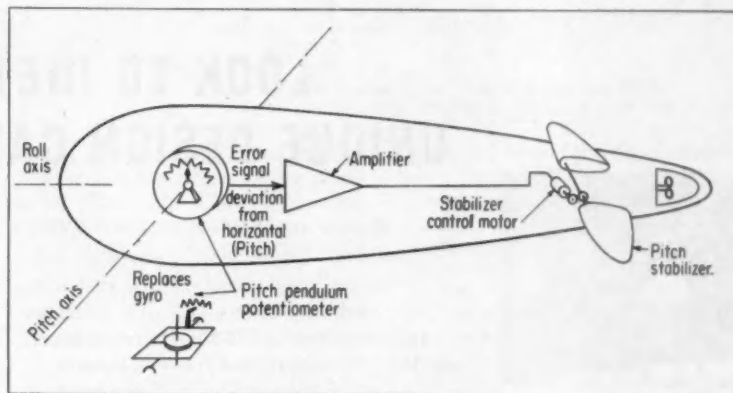


FIG. 1. Pendulum potentiometer has been used as pitch angle reference in torpedoes in place of much more expensive vertical gyros.

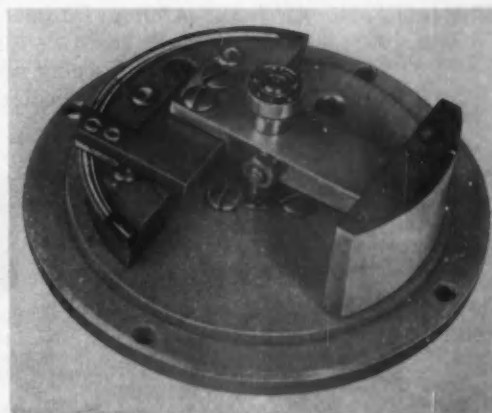
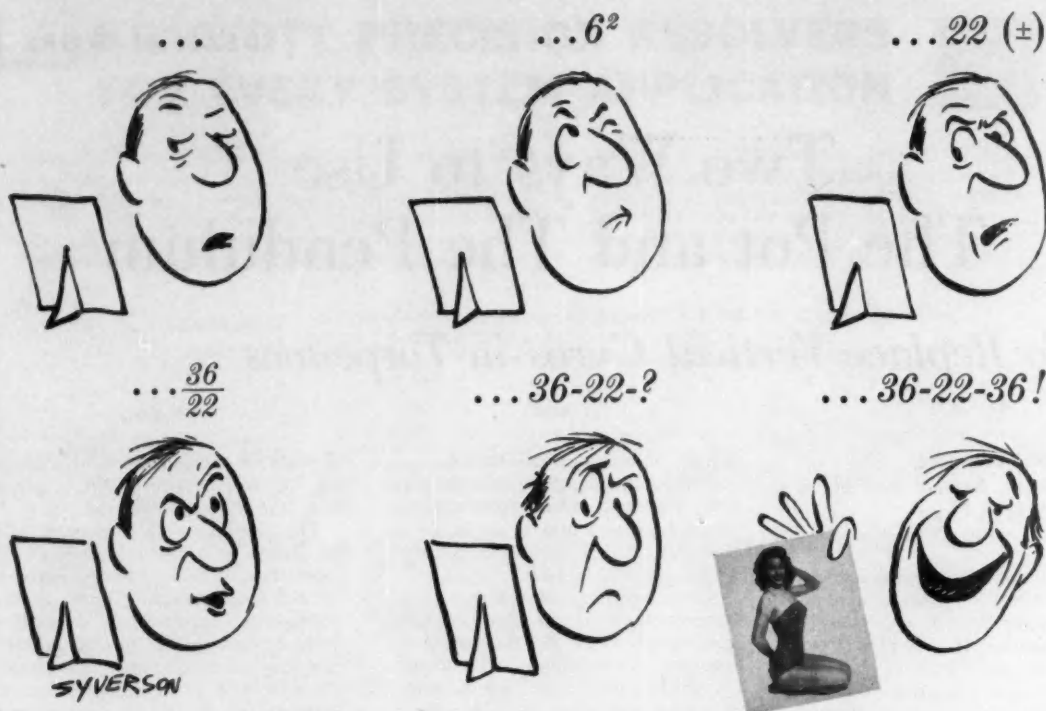
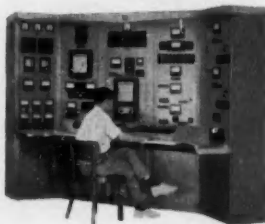


FIG. 2. Commercial pendulum potentiometer uses heavy tungsten mass to get high sensitivity in small case filled with silicone fluid for damping.



What's the size of your design problem? Facing a multiplicity of project details? It's no laughing matter when you're caught short-handed on a critical design program. You need proved engineering ability **plus** systems capabilities you can count on. Next time... **this time** —

LOOK TO INET FOR UNIQUE DESIGN CAPABILITIES



Here's another example of INET capability: the console, recorders and related instruments built, installed and wired by INET for Atomics International's L-54 nuclear research reactor. The solution-type L-54 reactor, which has a rated power capacity of 5,000 watts, was designed and built by Atomics International for the West Berlin Institute for Nuclear Research. It is being used for German scientific, medical and industrial research.



Engineers desiring a special reprint of the cartoon above should write to "36-22-36," % Inet Division, Leach Corporation.

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2. For Automatic Leveling on Road Graders

THOMAS THOMPSON
MELVIN PFEIFER
Sanders Associates, Inc.

The pendulum potentiometer is the reference for control of the angle of the cutting blade in a new automatic control system for road graders. Modern highway construction standards are generally such that a finish cut 10 ft wide should be controlled in angle by a road grader to within one milliradian, or one-eighth of an inch in 10 ft. Without automatic blade angle control, this requirement could cause a bottleneck in the planned road building programs. Figure 1 shows the Galion road grader with automatic blade angle control doing level finish grading. Figure 2 is a phantom drawing which pictures the blade angle control elements.

The operator of the road grader can regulate on a dial the angle of his cutting blade at any position between 90 deg and horizontal. Either end of the blade can be manually controlled in elevation and the control system automatically controls the other end of the blade to maintain the desired angle of cut while finish-grading.

A road grader automatic blade control system must perform so that the grader can finish-grade any slope:

- while moving at speeds up to 5 mph during final grading
- while traveling on slopes up to 30 deg from horizontal

Realistic dynamic response requirements call for following road input signals up to 0.15 cps and operator input signals, through the blade's manually operated end, up to 1 cps.

The blade angle controller is a feedback control system, Figure 3. The angle of the grader frame relative to vertical is sensed by the pendulum potentiometer. Manual dial selection of the desired cutting angle positions the potentiometer case in rotation relative to the grader frame. The input signal to the feedback control system is the electrical signal from this reference potentiometer.

The feedback potentiometer measures the blade angle relative to the grader frame. The reference potentiometer and the feedback potentiometer are connected in a bridge circuit. The bridge output signal is



FIG. 1. Angle of finish grade is maintained automatically on this road grader by control system that uses pendulum potentiometer as reference.

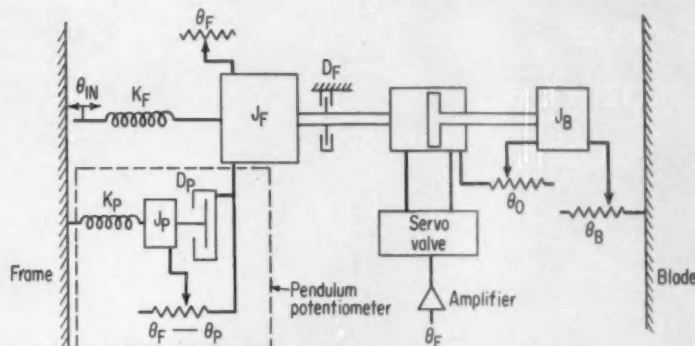


FIG. 2. Road grader blade control system. K_p is effective spring constant of pendulum mass due to gravity.

proportional to the selected cutting angle minus the actual cutting angle of the blade. This is the error signal in the primary servo loop.

The primary loop could be closed with sufficient open loop gain, even without adding stabilizing elements, to meet the requirements for response to road input signals. But stabilization was necessary to meet the response requirements for operator command signals.

Passive electrical stabilizing networks were considered but abandoned in favor of a judicious selection of the pendulum natural frequency and damping ratio. It was found analytically and verified experimentally, that if the pendulum natural frequency is near the load natural frequency, overdamping the pendulum will reduce the effect of the load resonance. Damping tends to carry the pendulum along with the frame motion, thus reducing parasitic feedback.

The major problem with this design was to have a relatively high pendulum frequency of preferably 3.7 cps but at least 1.5 cps and yet have sufficient

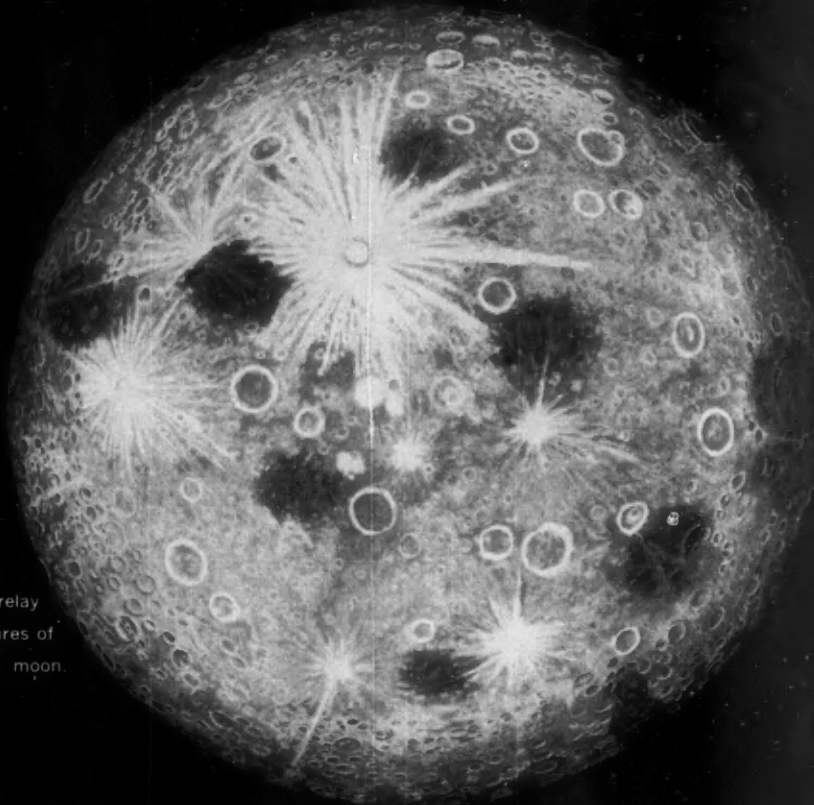
pendulum torque to obtain resolution of a fraction of a milliradian. It should be noted that the natural frequency of the simple pendulum is independent of the weight of the bob and depends only upon the length of the rod and the acceleration of gravity. An acceptable frequency response was achieved by about a 4.5-in. pendulum rod. A bob weight of about 7 lb developed sufficient torque to overcome all friction and resolve angle error down to 0.1 milliradian by actual test. The pivot of the pendulum was located at a point in the grader where side motion due to the blade motion was almost negligible.

The accuracy, stability, and response of the control system has met specifications. The initial feedback of information from road tests indicates the operator can do better finish-grading at faster speeds, with the automatic blade controller than without it. It appears that less training will be required for an operator of this equipment than for operators of more conventional road graders.

* This scientific representation based on current knowledge was prepared under the supervision of Dr. I. M. Levitt, Director of the Franklin Institute Planetarium.

THE OTHER SIDE ? *

Soon space probes will relay
back to the earth pictures of
the other side of the moon.



WILL IT LOOK LIKE THIS ?

At this time no one knows. But intricate electronic devices in projected lunar vehicles will reveal this hidden surface. Instrumentation has extended the long arm of man to reach as far as the mind can project. With such devices as a key, science can unlock the door to the future and to the very universe itself.

At the Decker Corporation our sole occupation is instruments—instruments which range from a device to measure a millionth of an inch on earth to one recording the density of the most tenuous of the space atmospheres subject to man's reach.

On the mysterious road to space will be found Decker instruments to provide beacons to light up the future.

THE DECKER CORPORATION Bala Cynwyd, Pa.

NEW PRODUCTS

IONIZATION DETECTION SYSTEM boosts chromatograph sensitivity and resolution.

The Barber-Colman gas-liquid chromatographic ionization detection system is based on the idea that under certain conditions the introduction of minute impurities in the form of a gas or an organic vapor to a chamber containing a flowing stream of argon greatly increases the ionization produced by a radioactive source. In this case, "impurities" are the components of the sample eluted from the chromatograph's column. This increased ionization seems to be caused by the presence of highly excitable, but nonionized atoms in the parent gas which—upon collision with the component vapors in the ionization chamber—transfer their excitation energy to the molecules of the eluted component. In the process, the organic vapor is ionized and a pair of ions is collected in the chamber.

The potential necessary for the production of metastable states varies considerably with the type of noble gas used. Since the ionization potential of many organic compounds and gases that are usually analyzed by gas-liquid and gas-solid chromatography is below that of the excitation potential of argon, transfer of energy occurs and large increases in ionization current are readily produced. When the voltage applied to the ionization chamber is increased, this effect is greatly magnified and provides the analyst with a sensitive, rugged, and simple detection system.

The Barber-Colman Model 10 detection system shown in the accompanying photo features a maximum sensitivity of 10-11 moles, about 1,000 times the sensitivity of thermal conductivity devices. This offers higher column efficiencies and greater resolution. The maker claims the system is insensitive, over a wide range, to changes in flow, pressure, and temperature. Other features are column lengths from 4 to 20 ft., column temperature control, provisions for fast heatup and rapid cooling of the column,



flash heating to volatilize the sample, a temperature indicator, a recorder, and a recording integrator giving a digital (pips) indication of the area under the component curves.

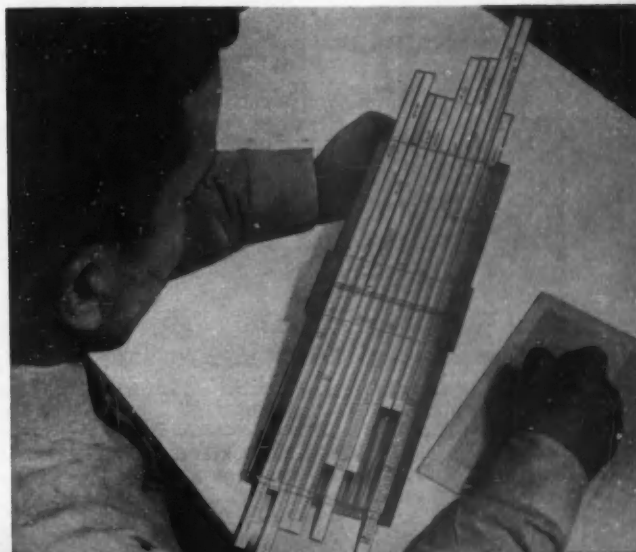
In addition to the Model 10, a smaller system has been designed specifically for petrochemical and similar applications. Portable and compact, this model uses a capillary column only.—Barber-Colman Co., Wheelco Instruments Div., Rockford, Ill.

Circle No. 200 on reply card

NEW SLIDERULE speeds analysis.

The Direct Reading Frequency Response Sliderule shown here permits the simultaneous determination of amplitude ratio and phase vs. frequency for all terms of a complex transfer function. Amplitude ratio and phase information is presented as numbers for direct readout at 20 frequency intervals per decade through six decades. Because a single setup provides all this information, the rule is ideal for studying the effects of variation in system parameters, the optimization of compensating networks, and the effects of high-frequency terms. The rule contains 11 channels; one holds a frequency scale covering six decades from 0.001 to 1,000, and each of the remaining 10 holds a scale representing one term of the transfer function. A complete set includes 24 such function scales, any 10 of which can be in the rule at one time. One side of the function scale carries amplitude ratios, the other side phase angles.—Boomshaft & Fuchs, Huntingdon Valley, Pa.

Circle No. 201 on reply card



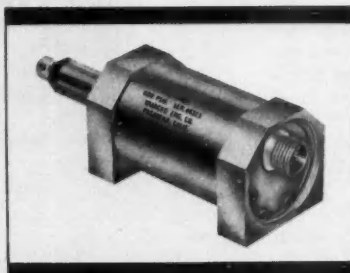
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...to get his silver dollar back?

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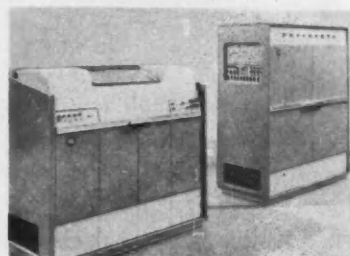
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CIRCLE 60 ON READER-SERVICE CARD

NEW PRODUCTS

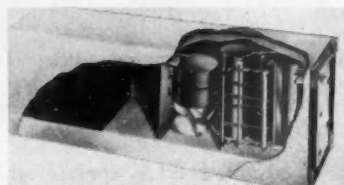
DATA HANDLING & DISPLAY



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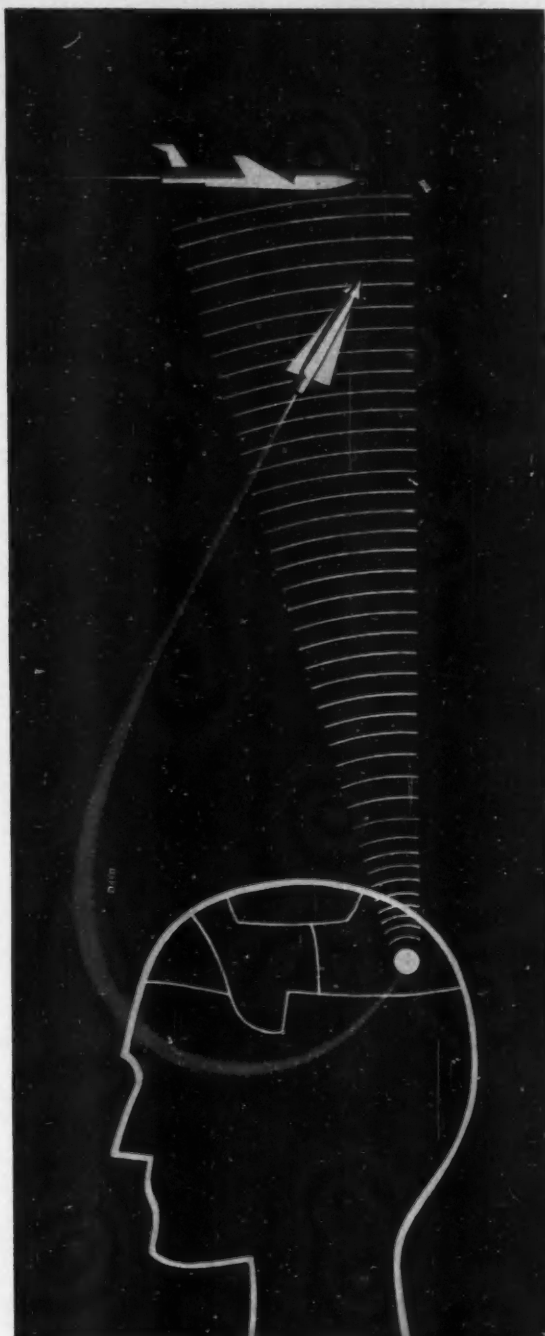
This solid-state line printer, designed for the Burroughs 220 data processing system, will select, edit, and print out data from a computer or magnetic tape at rates up to 1,500 lines per min. Suitable for either on-line or off-line operations, it consists of two units, a drum printer and a transistorized control unit. The latter houses a magnetic core buffer and plugboard editing controls. Printer's vocabulary contains 51 solid-face characters, which print in lines of 120 positions. Printing density is 10 characters per in. —ElectroData Div., Burroughs Corp., Pasadena, Calif.

Circle No. 202 on reply card



RECORDS FLIGHT HISTORY

Shown is a 20-lb multichannel flight-data recorder designed to exceed minimum CAB specifications. Completely self-contained, the unit senses and records all CAA-TSO needs except vertical acceleration. For this, an external accelerometer is provided. Flight data is inscribed on a specially coated metallic tape. The record magazine holds 200 ft of tape, enough for 200 flying hours. Both sides of the tape can be used, each side being capable of handling seven different channels. Initially, units will be used to record only the CAB required heading, air speed, altitude, time, and vertical acceleration. Later, airline



From Bell Telephone Laboratories...

Brainpower for the brawny Nike-Hercules

The Army's newest surface-to-air guided missile—the lethal Nike-Hercules—is now operational. Because it is, no unfriendly plane will be able to fly sufficiently high, fast or evasively to escape a fatal rendezvous with it.

For Hercules has a “brain”—an intellect that makes it a prodigy among today's electronic robots. Bell Telephone Laboratories developed it. Western Electric (prime contractor for the entire missile system) is producing it. Douglas Aircraft Company is giving it its body.

This “brain” is a fully integrated guidance system, almost entirely land-based. Only the vital signal-receiving apparatus is expendable within the missile itself. Other highly practical features: it defies “jamming,” is completely mobile, is designed in separate “building block” units which are replaceable in seconds—and is deadly accurate.

Bell Labs scientists and engineers designed the world's largest and most intricate telephone communications network for the Bell System. They developed about half of the Armed Forces' radar equipment during World War II. And they pioneered the nation's *first* successful air defense guided missile system—Nike-Ajax.

They were eminently qualified to give Hercules the brainpower it needed.

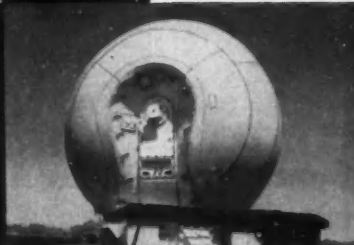


BELL TELEPHONE LABORATORIES

World center of communications research and development



Vigilant acquisition radar for Nike-Hercules first detects approach of distant aircraft, pinpoints its location and instantly signals to battery control.



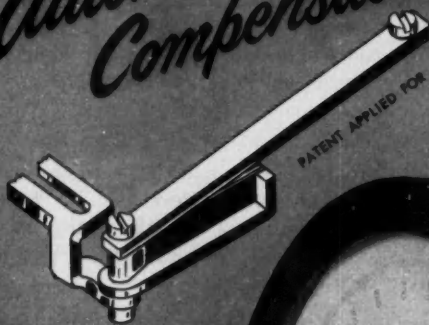
Two tracking-radar antennas, housed in radomes, take over. One feeds target azimuth, elevation, range data to computers; other tracks Hercules.



Two sets of radar data are electronically computed and plotted. Hercules is “steered” by radio signals, then detonated at precise point of interception.

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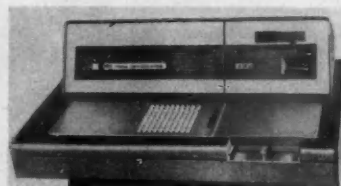
110

CONTROL ENGINEERING

NEW PRODUCTS

operators may want records of engine exhaust temperature, cabin temperature, and pressure, fuel flow, engine rpm, etc. —Waste King Corp., Los Angeles, Calif.

Circle No. 203 on reply card



PRODUCES PUNCHED TAPE

Called the pdp/Data Integrator, this simple, compact, desk-top machine handles peripheral data processing in tabulating equipment and systems. The unit accepts fixed data from tabulating or edge-punched cards and variable data through its simple keyboard. These two inputs are automatically integrated and punched out on paper tape. Applications include such accounting operations as inventory and stock control, banking and brokerage operations, and production control. Manufacturer says the unit will cut tabulating card files in half and double productivity. —American Electronics, Inc., Brooklyn, N.Y.

Circle No. 204 on reply card

OPTICAL CHART READER

A new automatic chart reader, suitable for strip or circular charts, film, or photographic traces, produces a pulse-width-modulated output signal proportional to the ordinate of the trace being read. Scanning is performed optically as the chart or other record is advanced. Nominal scan rate is 7,200 times per min, and accuracy is within 1 percent full scale. Optional equipment includes conversion and computing units. Output may be stored on punched cards, punched tape, or magnetic tape, or displayed on automatic printers. —The Geotechnical Corp., Dallas, Tex.

Circle No. 205 on reply card

PLUS . . .

(206) A new series of low cost counter-controllers for industrial applications has been developed by Berkeley Div., Beckman Instruments, Inc., Richmond, Calif. . . . (207) Telemeter

CIRCLE 62 ON READER-SERVICE CARD →

IMPORTANT ANNOUNCEMENT



New family name for Robertshaw level measurement and control instruments

Effective January 1, 1959, Robertshaw will adopt more uniform and meaningful trade names to identify its line of capacitance instruments.

If you are engaged in mining, refining, processing or manufacturing...if you utilize or encounter liquids, granular solids, powders and interface...you can rely on these time-tested products.

LEVEL-TEK (formerly *Tektor*) — An on-off device which operates local or remote warning devices or motor-driven valves and pumps when a predetermined level has been reached.

LEVEL-TEL (formerly *Telstor*) — A continuous level system which detects, measures and visually indicates changes in media level.

LEVEL-SET (formerly *Pneutronic Level Controller*) — An instrument which converts changes in level to proportional changes in air pressure for maintaining a constant head in vessels where pneumatic feed control systems are employed.

LEVEL-LOG (formerly *Series 42 Recorder-Controller-Indicator*) — A versatile and extremely accurate RF null balance capacitance system for level measurement, recording and control.

AERONAUTICAL AND INSTRUMENT DIVISION

Robertshaw-Fulton

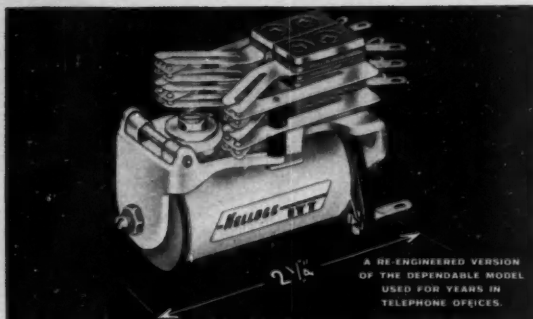
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- Bifurcated stationary springs:** for independent contact action and high reliability (single contacts also available).
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- Single or double arm type armatures available.**
- Hermetically sealed models, if desired.**
- Operating speed:** minimum of 1-2 milliseconds.
- Contact points:** gold, silver, palladium, tungsten; others available.
- Residual:** adjustable and fixed.
- Time delay:** heel-end slugs and armature-end slugs for release time delay and operate time delay, respectively.
- Terminals:** slotted.
- Weight:** net, 2-1/4 oz.
- Dimensions:** 2-1/4" L x 1-1/8" W, height ranges from 17/32" to 1-1/16" (max.)
- Operating voltages:** up to 220 volts D.C.

Backed by Kellogg and International Telephone and Telegraph Corporation. Inquiries are invited. Send for a free catalog on Kellogg relays, components.



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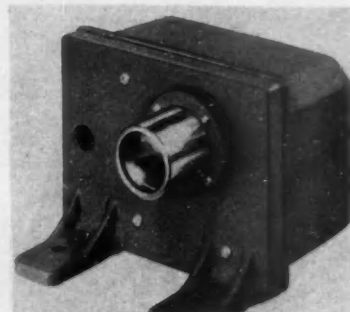
CIRCLE 63 ON READER-SERVICE CARD

NEW PRODUCTS

Magnetics, Inc., Los Angeles, Calif., recently came up with an auxiliary core storage buffer designed to save computer time in data processing. . . . (208) A Model 521 transistorized digital totalizer, by Potter Aeronautical Corp., Union, N. J., features a 10-mv-sensitivity and switch-controlled range extension. . . . (209) A new oscillogram processor now being marketed by Consolidated Electrodynamics Corp., Pasadena, Calif., uses a thermistor for drum temperature control.

Circle No. 206, 207, 208, or 209 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



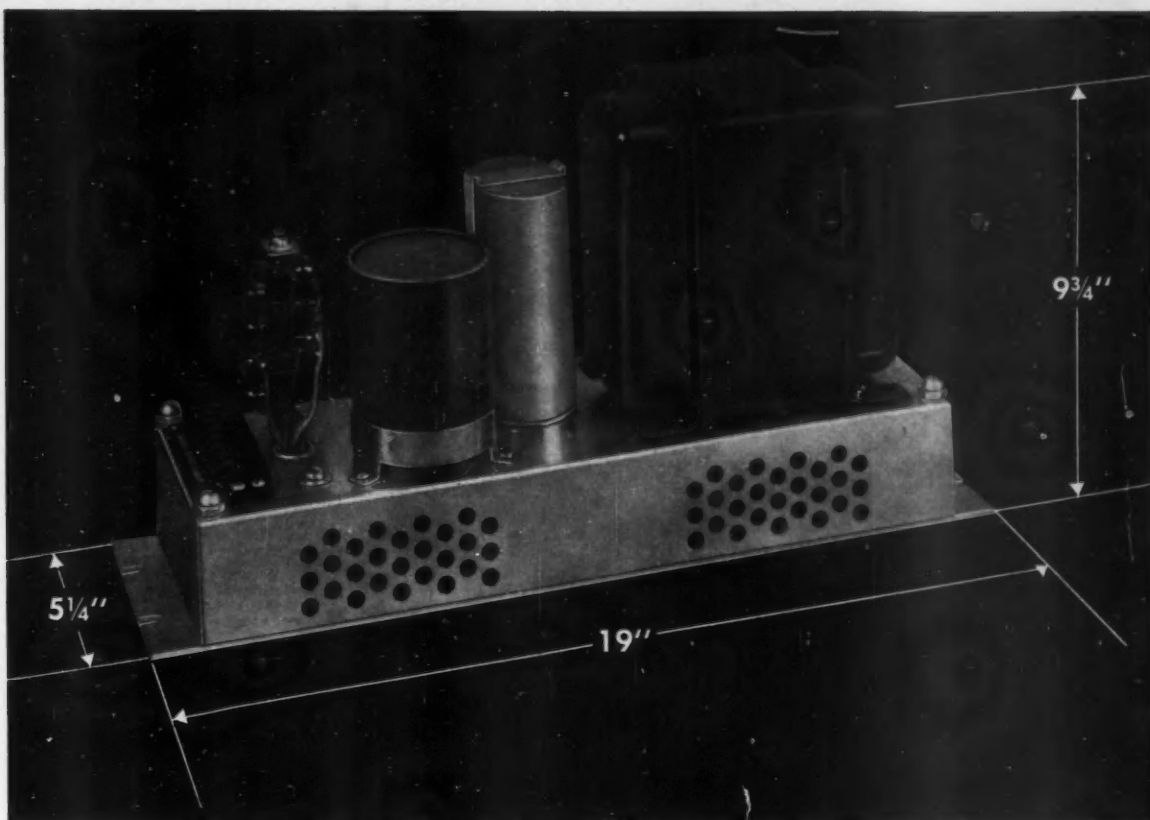
FAST WITHOUT TUBES

Pictured is a relatively high-speed photoelectric control, Model BM-1, which uses no tubes. Instead, it contains a cad cell sensing element and magnetic amplifier. The unit requires a minimum light of 10 foot-candles with a 0.04-sec minimum dark time. Minimum light time is also 0.04 sec. Control relay contacts are dpdt, silver-cadmium oxide, rated for 10 amps at 115 vac. Cast aluminum housing features a splash-proof gasket seal.—Autotron, Inc., Danville, Ill.

Circle No. 210 on reply card

EXPANDABLE SYSTEM

A new strain gage system offers a wide choice of arrangements for operating an adding machine, printer, Flexowriter typewriter, and tape punch unit. Standard rack-mounted units permit rapid assembly of a 10-channel system that will select, measure, and record strain-gage data from each channel,



Sola Constant Voltage DC Power Supplies are designed for intermittent, variable, pulse or high-ampere loads.

Sola packs 6 amps of 300-watt regulated dc power into 5 1/4 inches of relay-rack space

Looking for a source of regulated dc power that fits into a small space? You'll probably find that the Sola Constant Voltage DC Power Supply offers what you want.

This compact unit has exceptional performance characteristics, too—it delivers current in the "ampere range," regulates within $\pm 1\%$ even under a $\pm 10\%$ variation in line voltage, has less than 1% rms ripple, and even tolerates dead shorts. It is 80% efficient and has a very low static output impedance.

How's it done? Sola managed it through a balanced assembly of three complementary components . . . a special Sola Constant Voltage Transformer is teamed up with a semiconductor rectifier and a high-capacitance

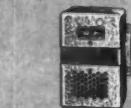
filter. Electrical characteristics of the transformer maximize most of the advantages of the rectifier and filter, while virtually eliminating all their disadvantages. The resulting regulated dc power supply is simple, highly reliable, compact and moderately priced.

These benefits are exhibited by the entire line of Sola dc power supplies. Sola has designed and produced hundreds of ratings to meet requirements of equipment manufacturers. The company is set up to handle specific needs for custom-designed units in production quantities. A Sola sales engineer can supply all the facts. In addition to this custom service, Sola currently stocks six models ranging from 24 volts at six amps to 250 volts at one amp.

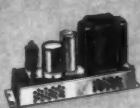
For complete data write for Bulletin 26B-CV-235.

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FLUORESCENT LAMP BALLASTS

A DIVISION OF BASIC PRODUCTS CORPORATION



The artist has captured a rare expression on the face of Sigma's general manager—one of happy satisfaction and complete contentment. This is because the sales dept. has just told him (1) about a new Machine of Pleasure which uses a Sigma product and (2) that the customer is overjoyed because the Sigma product works right. His corporate corpulence is enjoying every minute of it, while it lasts. By publicizing this latest application triumph, it is hoped that others will be spurred on to similar successes.

An enterprising consulting engineer on the West Coast recently took on the job of building a fully automatic machine for folding Chinese fortune cookies. The specs called for handling a piece of hot, flexible cookie dough every five seconds; folding it in two directions and getting the fortune inside the cookie between folds; using up 420 different fortunes before repeating. The machine slices printed fortunes as required from continuous rolls. It was at this point that consulting cookie engineer William E. Thomas asked his E. E. brother Frank how to keep the slices between the lines; since brother Frank reads Sigma ads, his immediate reply was "Sigma Photorelay" (we like to think). One was purchased and rigged up to control the paper feed, by sensing black bars printed on the rolls. Brothers Thomas, their project engineer Charles A. Lindberg (honest!), their customer and Sigma are now all entranced by the results.

So one more banner should be raised for the unsung heroes whose accomplishments do not go up in three stages and a deafening roar, but simply "kerplunk" every few seconds as a new little item is unfailingly produced. If you have such a project, and light sensing can be put to a useful purpose, a Sigma Photorelay might be worth trying.

They come ready to plug in, switch 3 amps. resistive at 120 VAC, cost only about \$12.00; the cookie boys even went so far as to say "we certainly could not have installed anything else that worked properly so inexpensively." Who knows, maybe you could even build a machine to get the ordinate and abscissa straight on hot cross buns.



SIGMA

SIGMA INSTRUMENTS, INC.

69 Pearl St., So. Braintree 85, Mass.

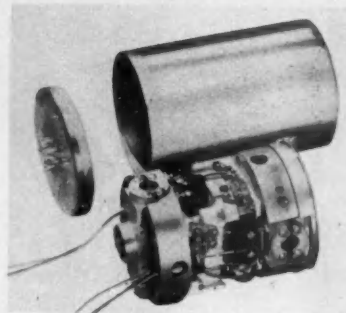
AN AFFILIATE OF THE FISHER-PIERCE CO. (Since 1908)

CIRCLE 65 ON READER-SERVICE CARD

NEW PRODUCTS

sequentially and automatically. Modular design allows the user to add more 10-channel units without rewiring or modifying the initial installation.—Datran Electronics, Manhattan Beach, Calif.

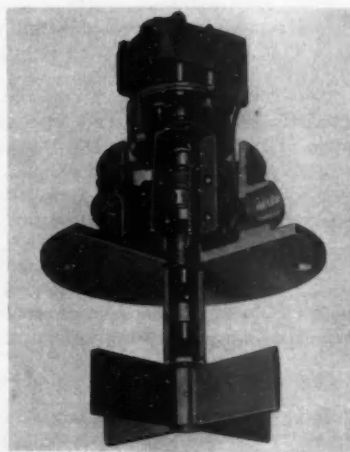
Circle No. 211 on reply card



DUAL RATE GYRO

Shown above with cover removed, the new RG-18 series gyro saves space by using one motor to drive two separate wheels. This permits measurement of rates about two different axes. Another type, the RG20 series, will cover two rate ranges about the same axis. Both models have two independent pickoffs and are designed to meet rigid environmental conditions — Humphrey, Inc., San Diego, Calif.

Circle No. 212 on reply card



CHECKS BULK LEVEL

Called a Bin-Vue level indicator, this device indicates high or low levels in any type of bulk storage bin. New features include rapid access for servicing and fail-safe operation. When material

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	2N1100	2N1099	2N174A	2N174	2N173	2N278	2N277	2N443	2N442	2N441
Maximum Collector Current	15	15	15	15	15	15	15	15	15	15 amps
Maximum Collector Voltage (Emitter Open)	100	80	80	80	60	50	40	60	50	40 volts
Saturation Resistance	.02	.02	.02	.02	.03	.03	.03	.03	.03	.03 ohms
Thermal Gradient (Max.) (Junction to Mounting Base)	.8	.8	.8	.8	.8	1.0	1.0	1.0	1.0	1.0 °C/watt
Base Current I_B ($V_{EC}=2$ volts, $I_C=5$ amps)	135	100	135	135	100	100	100	150	150	150 ma
Collector to Emitter Voltage (Min.) Shorted Base ($I_C=.3$ amps)	80	70	70	70	50	45	40	50	45	40 volts
Collector to Emitter Voltage Open Base ($I_C=.3$ amps)	70	60	60	60	50	45	40	55	45	40 volts

*Designed to meet MIL-T-19500/13A (Jan) 8 January 1958 †Formerly DT100 ‡Formerly DT80

Check your requirements against the *new, improved* characteristics of Delco High Power transistors. You will find improved collector-to-emitter voltage . . . higher maximum current ratings—15 amperes, and extremely low saturation resistance. Also, note the new solid pin terminal design.

And of special importance to you is the fact that diode voltage ratings are at the maximum rated temperature (95°C.) and voltage.

Write today for engineering data on the *new, improved* characteristics of *all* Delco High Power transistors.

DELCO RADIO

Division of General Motors • Kokomo, Indiana

BRANCH OFFICES

Newark, New Jersey
1180 Raymond Boulevard
Tel: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

CIRCLE 66 ON READER-SERVICE CARD

FEBRUARY 1959

115



-and now the vibration test!

Shock — testing on the rocks? If vibration and shock are your headache, you *could* build your own pots to lick this problem! But look out for foul play in the shaft and bushings, under shock — you can lose your accuracy right *there*! And make sure your pet design includes a contact with no resonances, minimum mass, low wiper pressure — yet with excellent linearity! Oh, you'll be plenty busy!

But the easy way is to come to Ace! Our shockless pots incorporate, through exclusive precision production methods, fantastically close bearing fit. And our own specially balanced contacts place extremely low mass at the edge-wipe end, under low brush pressure, for steady contact under shock. Tempered precious metals and low contact resistance mean long, corrosion-free wear. Tested to 50 G's at 2000 cycles.

Our complete pot line incorporates all these anti-shock design features. Under extreme servo applications, this 1/2" servo-mount Series 500 Acepot delivers 0.3% linearity.



ACE ELECTRONICS ASSOCIATES, INC.
99 Dover Street, Somerville 44, Mass.
SOMerset 6-5130 TMX SMVL 181 West. Union WUX

Acepot® Acetrim® Aceset® Aceohm® *Reg. Appl. for

CIRCLE 67 ON READER-SERVICE CARD

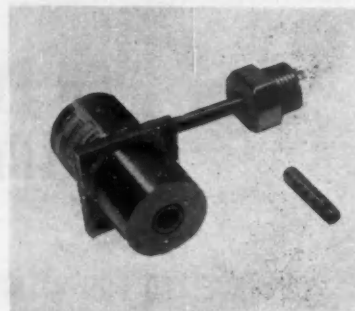
CONTROL ENGINEERING

116

NEW PRODUCTS

is below the level of the indicator, a 1/100-hp motor turns a four-blade paddle at 9 rpm. As soon as material makes contact with the paddle, the paddle stops, a spring winds up actuating a limit switch, and the motor stops. When the level drops, the spring unwinds, again actuating the switch, and the motor starts. Signals from the switch may be used for alarms and indicators.—Compass Research Associates, Pittsburgh, Pa.

Circle No. 213 on reply card



EXPLOSION-PROOF

Suitable for use in corrosive and flammable liquids, this recent addition to the company's line of differential transformers features a welded stainless steel housing that eliminates need of any further enclosure. Its stepless output voltage is a precise linear function of core displacement within the specified operating range. Temperature range is minus 65 to plus 450 deg F; pressure range is to 5,000 psi.—Schaevitz Engineering, Pennsauken, N. J.

Circle No. 214 on reply card

LOW-FLOW PICKUP

Designed to sense flow rates as low as 0.002 gpm, the Mark X transducer consists of a miniature variable-area meter whose float is connected to the core of a differential transformer. The unit thus translates flows at high static pressure and temperature into a linear electrical signal. Suggested applications include engine or servovalve test stands and laboratory evaluation of hydraulic systems and industrial process controls. Simplified construction permits range changing in the field.—Ramapo Instrument Co., Bloomington, N. J.

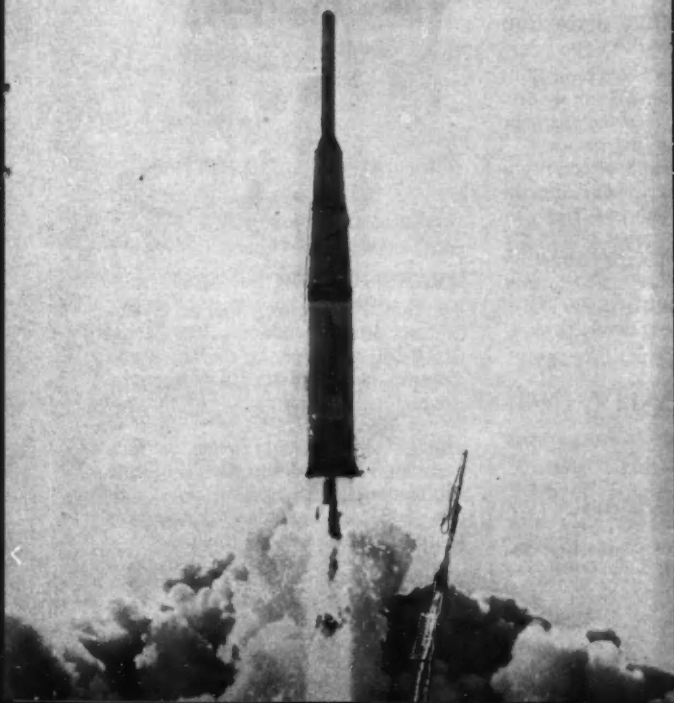
Circle No. 215 on reply card

the Pioneer in space

To send the U.S. Pioneer more than 60,000 miles into interplanetary space, Space Technology Laboratories in seven months designed, developed, assembled, and tested an 88-foot combination of three integrated stages with a payload incorporating 36 separate ignition systems. STL's Astrovehicles Laboratory focused on the payload itself and the sensitively related problems of propulsion, weight, and stability. These are in addition to the overall complexities of the structural configuration.

Pioneer, setting new apogees in science and missilery, typifies the achievements STL is making in the advancement of space technology. Those who are able to contribute to and benefit from these developments are invited to consider joining our staff.

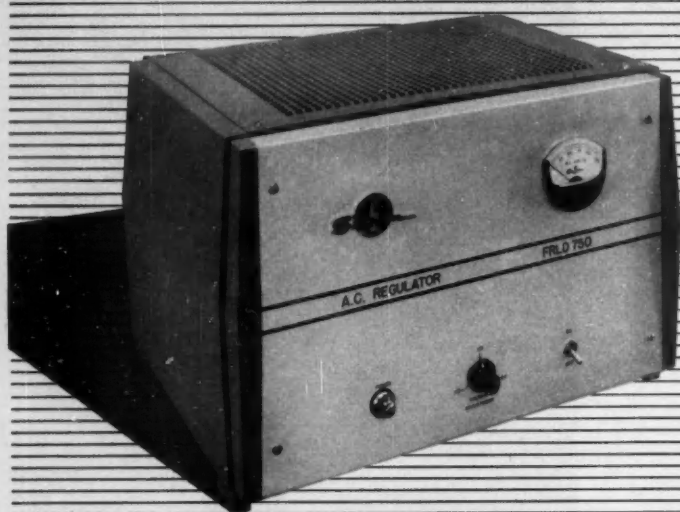
Space Technology Laboratories



Space Technology Laboratories, Inc.
5730 Arbor Vitae Street, Los Angeles 45, California

NEW IDEAS IN PACKAGED POWER

for lab, production test,
test maintenance, or as a
component or subsystem
in your own products



New, fast, a-c regulator cuts line & load transients 18 db

• Steady-state line and load regulation to $\pm 0.5\%$ • Transients attenuated at least 8:1 (18 db) • Fast response—less than 1 cycle (0.02 sec) for 63% recovery • Less than 0.35% distortion

The new Sorensen Model FRLD750 fast-response, low-distortion a-c regulator is ideal for critical applications like null testing, meter calibration, and the powering of pulse-type circuits, such as those used in computers, where false triggering is not permissible.

Since there is no phase shift between input and output, the FRLD750 can also be used in multiples for the regulation of multi-phase power. Line and load transients are reduced by at least

8:1, regardless of their magnitude. Both cabinet and 19" rack-mounting models available. Write for technical data or see your Sorensen representative.

And don't forget, Sorensen engineers will be glad to discuss your special power requirements with you. They can help you select the proper a-c or d-c power supply, regulator, or frequency-changer from the widest transistorized line on the market, or assist you in designing special power systems. e.39



SORENSEN & COMPANY, INC.

Richards Avenue, South Norwalk, Connecticut

WIDEST LINE OF CONTROLLED-POWER
EQUIPMENT FOR RESEARCH AND INDUSTRY

IN EUROPE, contact Sorensen-Ardag, Zurich, Switzerland. IN WESTERN CANADA, ARVA. IN EASTERN CANADA, Bayly Engineering, Ltd. IN MEXICO, Electro Labs, S. A., Mexico City.

CIRCLE 68 ON READER-SERVICE CARD

NEW PRODUCTS

RATIO COMPUTER

A new scintillation detector of 4 pi geometry serves as a ratio computer in extremely low-level radiation measurements. Combined with either a single- or multi-channel analyzer, it determines the radiation energy level, identifies the radioactive isotope, and measures the amount. A counting time of 100 sec per subject permits a sensitivity of 5×10^{-10} curies for 1.5 mev gamma rays.—Radiation Counter Laboratories, Inc., Skokie, Ill.

Circle No. 216 on reply card

PLUS . . .

(217) George Ulamet Co., Newark, N. J., has developed a thermostat that will control noninductive loads up to 5 amps at 115 vac. . . (218) A spring-driven gyro for use in short-range missiles and target drones is available from the Waltham Precision Instrument Co., Waltham, Mass.

Circle No. 217, or 218 on reply card

RESEARCH, TEST, & DEVELOPMENT



TRANSISTOR-DIODE TESTER

Developed for testing the dc characteristics of semiconductors, the Model TDT-200 contains no batteries and requires no auxiliary motors, pulse generators, oscilloscopes, or external power supplies. Its wide selection of voltage and current ranges permits testing under conditions that duplicate semiconductor applications. Unit sells for \$295. —Transistor Electronics Corp., Minneapolis, Minn.

Circle No. 219 on reply card

FLOW

PRESSURE

TEMPERATURE



Control Any Process Variable

with a system based on

REPUBLIC'S NEW TYPE "VC" PNEUMATIC CONTROLLER

Here is an all purpose null-balance-vector controller for use with any pneumatic transmitter. Its proportional band ranges from 2% to 500% *without changing parts*, for quick adaptation to changes in process requirements. Especially important in high-precision control, Republic's Type VC has exceptional sensitivity and a narrow dead band (less than 0.05%). Its high capacity non-bleed pneumatic amplifier consumes little air, keeps output ample. A selector block permits reverse or direct action. Local or

remote pneumatic set point optional.

Companion instruments—using an identical null-balance-vector "heart"—include differential pressure, temperature and pressure transmitters . . . ratio, totalizing, multiplying, squaring and square-root-extracting relays. Many parts are interchangeable among the instruments in this "family". Besides reducing spare parts inventory, the similarity of components simplifies the task of training personnel.

Let a Republic engineer show

you how these instruments can help to achieve accurate, efficient, dependable control systems. Republic Sales Offices are located in principal cities throughout the U.S.A. and Canada.

**REPUBLIC
FLOW METERS CO.**

Subsidiary of **ROCKWELL MANUFACTURING COMPANY**
2240 DIVERSEY PARKWAY CHICAGO 47, ILLINOIS
In Canada: Republic Flow Meters Canada, Ltd.—Toronto
Manufacturers of electronic and pneumatic
instrument and control systems for utility,
process and industrial applications.



CIRCLE 69 ON READER-SERVICE CARD

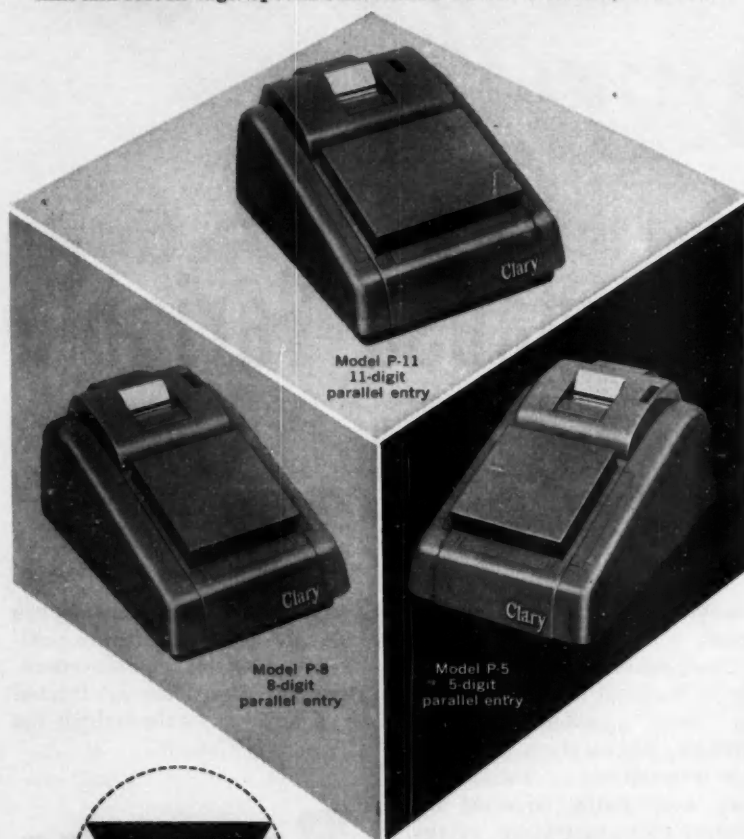
FEBRUARY 1959

119

7-DAY DELIVERY

on any 3 standard data printers

Now from Clary! Data printers delivered to you in a fraction of the usual time! Only Clary offers you 3 standard data-printing models with your choice of special dials and punctuation. Years of experience in this field have shown that these 3 standard models can be used in 85% of all data-printing applications...and at tremendous time and cost savings. Special built models are also available, if needed.



Model P-11
11-digit
parallel entry

Model P-8
8-digit
parallel entry

Model P-5
5-digit
parallel entry



Manufacturer of Industry's most versatile data printers

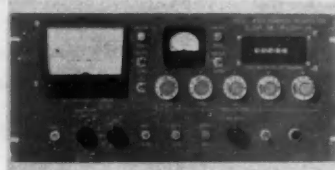
ELECTRONICS DIVISION

Clary Corporation, San Gabriel, California

Manufacturer of business machines, electronic data-handling equipment, aircraft and missile components.

CIRCLE 70 ON READER-SERVICE CARD

NEW PRODUCTS



INTEGRATES CHARGE

Designed particularly for use with high-voltage particle accelerators, the A-309 current integrator suits any application requiring measurement of accumulated charge in a fluctuating current. It features a special register and a set of five switches that permit presetting of any five-digit count. When the register reaches the preset number, an internal relay closes to actuate a warning bell or light. — Elcor, Inc., Falls Church, Va.

Circle No. 220 on reply card



FREQUENCY STANDARD

Available in two models, the type MLS Laboratory Frequency Standard exhibits a frequency stability of 5 parts in a billion per month after a 1-hour warm-up period. Frequency control is maintained in these compact transistorized units by means of a heater-controlled tuning fork. Model 60 offers two 60-cycle outputs, one a square wave at 7 volts peak-to-peak into 10,000 ohms and the other a 115-volt, essentially sinusoidal, output of 10 watts. Model 400 has output frequencies of 4,000, 1,000, 400, 100, and 50, with a power output of 10 watts at the 400-cycle frequency.—Accurate Instrument Co., Houston, Tex.

Circle No. 221 on reply card

TESTS FOR MISSILE LEAKS

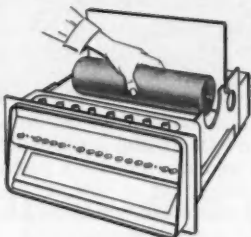
A new Halogen leak detector, consisting of a standard control unit and a variety of probes, has been developed for testing for propellant leaks in missiles. According to the manufac-

These features of
new Brush
ultralinear
recording
systems...

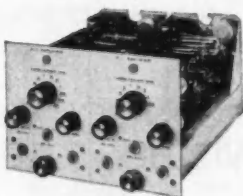


... give you more application versatility!

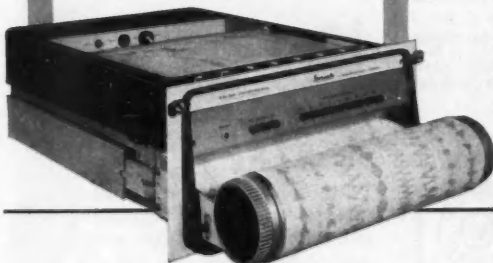
Simplified Chart Re-loading.



Interchangeable, plug-in
 signal conditioners.



Positive Chart Take-up Drive.



In the fields of telemetry, ground support systems, analog computing and laboratory testing, Brush recording systems have incorporated features which have consistently kept ahead of engineering requirements. Here are a few that show why—

INTERCHANGEABLE PLUG-IN SIGNAL CONDITIONERS. You get your choice of sensitivities—you get high input impedance—zero suppression.

SIMPLIFIED FAST CHART RE-LOADING. Loaded from the top—features automatic alignment and tracking.

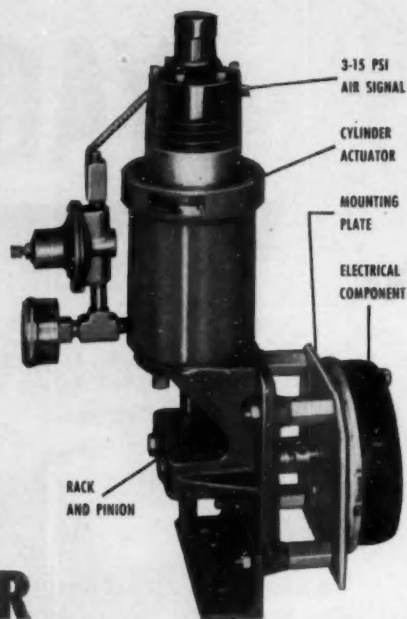
ACCURATE, EASILY REPRODUCIBLE RECORDINGS. Your choice of rectilinear or curvilinear charts—rugged "throw-proof" pens.

Illustrated above is a Brush RD-1684 rectilinear, 8 channel recording system. Sensitivity of 10 millivolts per chart line—input impedance, 10 megs balanced or 5 megs grounded. Complete system includes mobile cabinet, oscillograph and 8 signal conditioners. No additional preamplifiers required. Available from stock.

brush INSTRUMENTS

DIVISION OF
 37th & PERKINS **CLEVITE** CORPORATION CLEVELAND 14, OHIO

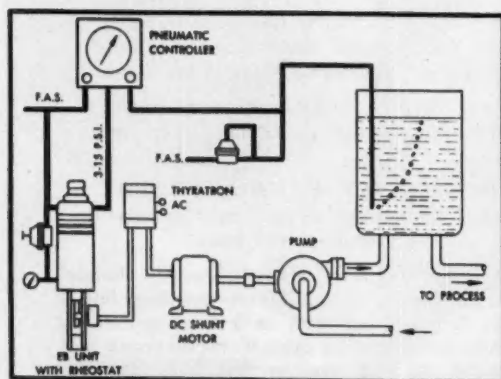
ELECTRIC CONTROL FROM A PNEUMATIC SIGNAL WITH THE CONOFLOW MODEL EB CURRENT CONTROLLER



The Model EB Current Controller—an exclusive product of Conoflow Corporation—is a unique final control element. It is a pneumatic-electric transducer consisting of a pneumatic cylinder actuator fitted with a rack and pinion mechanism, and a standard electrical component such as a rheostat, potentiometer or auto-transformer. The cylinder actuator, operating from a 3-15 psi air signal, produces a rotary motion (to 360°) to precisely position the electrical device affording automatic control of voltage, current, inductance, capacitance, resistance, or other electrical values.

APPLICATIONS—Conoflow Model EB Current Controllers are available from the factory in over 200 combinations of electrical components to handle a wide variety of applications. A few of these include:

- Constant Pressure
- Proportional Flow
- Liquid Level
- Temperature Control
- Machine Tool Speed
- Conveyor Control
- Heat Treating
- Humidity Control



A TYPICAL EXAMPLE

Direct flow regulation by varying pump speed is accomplished when the EB unit is used with a pneumatic controller and an electronic speed changer. It automatically positions the small rheostat in the grid circuit of a thyatron controlled speed changer, thereby adjusting motor and pump speed. This method of flow rate control can be used to provide control of temperature, pressure, pH, interface, or liquid level. It eliminates the valve, reduces motor power input, and provides for positive flow rangeability.

The EB unit with cylinder directly coupled to the armature or field rheostat of a DC shunt wound motor is also widely used for motor speed control.

For additional information on the Model EB Current Controller write to Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa., for Bulletin EB-3A.

CC-804



CIRCLE 72 ON READER-SERVICE CARD

122

CONTROL ENGINEERING

NEW PRODUCTS

turer, the instrument is sensitive enough to detect leakages as low as 0.01 oz per year. —General Electric Co., Schenectady, N.Y.

Circle No. 222 on reply card

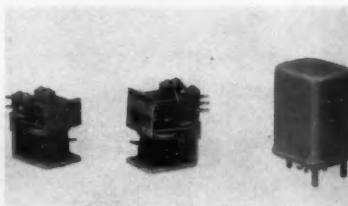


PORTABLE STANDARD

Pictured is a new portable pressure standard for calibration or direct parameter measurement. Interchangeable plug-in units, for gage, differential, or absolute pressures, provide an overall accuracy within 0.05 percent for ranges up to 2,500 psi. According to the manufacturer, other plug-in units will soon be available for measuring forces, accelerations, and temperatures. Since the unit incorporates a precision FM oscillator and an integral power supply, it can, with a remote pickup, provide a single-channel FM system.—Wiancko Engineering Co., Pasadena, Calif.

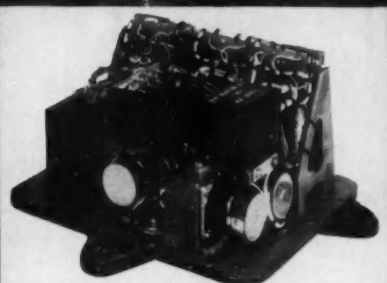
Circle No. 223 on reply card

CONTROLLERS, SWITCHES, & RELAYS



RELAY LINE

Features of this new relay line include tapered arms for distributed stress, nylon bobbins for longer service, and gold-plated silver contacts for more reliable performance. Line covers three



Three Gnat Gyros in Honeywell Three-Axis Turn Rate Transmitter. Size: 8.6" x 6.3" x 5.24". Weight: 5 pounds.



Convair F-106 all-weather jet interceptor incorporates Honeywell Three-Axis Turn Rate Transmitter in flight control damper system

Three-axis control at all speeds and altitudes



Gnat Rate Gyro shown 1/2 size. Weight: 3.8 ounces.

The Honeywell Three-Axis Turn Rate Transmitter, featuring three Gnat miniaturized gyros, was selected for the new Convair F-106 "Delta Dart" all-weather jet interceptor. Built into the stability augmentation sub-system of the jet's flight control system, the Transmitter detects rate of turn about the yaw, pitch and roll axes and responds with an output signal whose voltage is proportional to these input rates of turn.

This system is designed to operate under the most severe environmental conditions to which a combat aircraft might be subjected. The Honeywell Gnat Rate Gyros are easily capable of withstanding the severe shock, vibration and temperature requirements of this application and as such are mounted directly upon the base casting without shock mounts to optimize dynamic characteristics of the system.

The electronic portion of the Turn Rate Transmitter amplifies and demodulates the Gyro output signals to provide polarity reversing d-c outputs proportional to the corresponding input rate to each Gyro.

Investigate Honeywell's ability to develop, engineer and produce flight control systems for today's most advanced aircraft and missiles. Write for Bulletin GN to Minneapolis-Honeywell, Boston Division, Dept. 40 Life Street, Boston 35, Mass.

Honeywell



Military Products Group

BLONDER-TONGUE OFFERS A FREE SURVEY TO DEMONSTRATE HOW INDUSTRIAL TV CAN BENEFIT YOU

Industrial television (closed circuit TV), the newest means of visual communication, is now increasing profits and efficiency for industry, science and education. Undoubtedly, there is some area of your present operation (continuous process control, quality control inspection, data transmission, plant or property protection, monitoring gauge and instruments, safety, dispatching, etc.) that can be improved by the use of industrial TV. The question is—what area?... How will it be benefited?... and what is the cost?

Blonder-Tongue and its nationwide staff of specialists eliminate all the guess-work in industrial television by offering you a free survey in your plant, office, etc. to demonstrate where and how industrial television will benefit you, what an installation involves and the cost. With industrial TV increasing efficiency at companies and institutions similar to your own, you can't afford to miss this opportunity to find out at no risk, no obligation what industrial TV can do for you.

Many leading organizations now rely on Blonder-Tongue industrial TV systems. Included among them are U. S. Steel, Sharon Steel, Southwestern Portland Cement, Johnson & Johnson, E. I. Dupont, General Motors, Brunswick Pulp and Paper, Union Carbide, Douglas Aircraft, Public Service of New Jersey, Los Angeles Dept. of Water and Power, St. Mary's Hospital, Albert Einstein Medical Center, West Phoenix High School and many others.

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industrial TV systems • master TV systems • high fidelity components • TV products • FM-AM radios



A completely automatic Blonder-Tongue industrial TV system (compact, rugged camera; automatic light compensator; TV monitor) providing quality pictures can be installed for less than \$2,500.00.



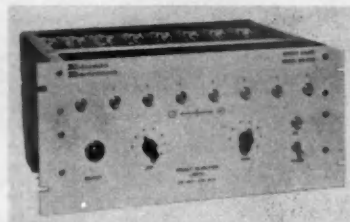
CIRCLE 74 ON READER-SERVICE CARD
CONTROL ENGINEERING

124

NEW PRODUCTS

types: CR, rated at 5 amps and available up to 4 pdt; CP, a 10-amp dpdt type; and CS, a sensitive unit suitable for operation in vacuum-tube plate circuits.—Cardinal Control Co., New Britain, Conn.

Circle No. 224 on reply card



MISCUT GAGE

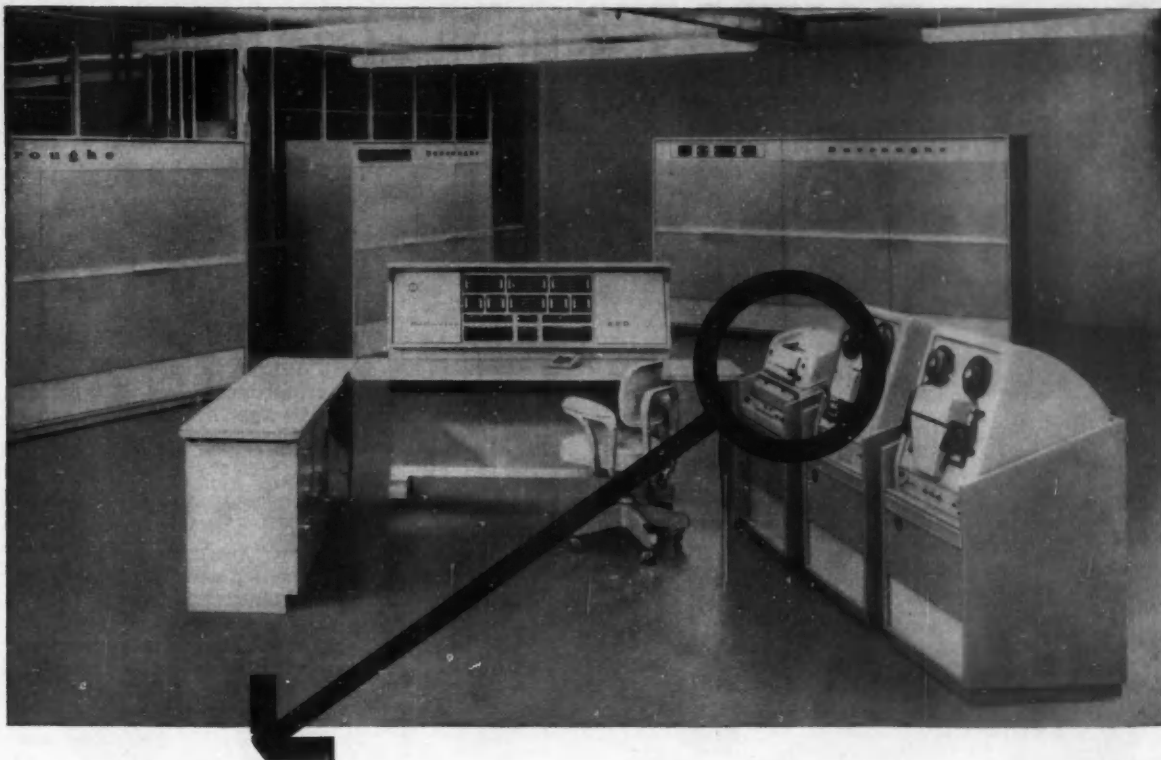
Designed originally for steel-mill application, the MG-800 miscut gage will control length, width, or shape of any material fabricated in discrete elements. Eight "reader" photocells and an "interrogator" photocell are positioned in a bank along a conveyor so that the leading edge of the sheet crosses the interrogator position when the trailing edge is over the bank. Eight pilot lights on the control unit, shown above, correspond to the reader photocells and represent 1/32-in. increments of length. Thus tolerance limits from plus or minus 1/64 to 7/64 in. may be set up on the control panel. An out-of-tolerance sheet produces an output signal from the control unit that can then be used to actuate an alarm or operate an automatic reject system. Maximum sheet velocity is 50,000 fpm.—Eldorado Electronics, Berkeley, Calif.

Circle No. 225 on reply card



CAM-OPERATED SWITCH

Rugged construction, long life, and accuracy are features of a new, low-cost snap-action switch designed for cam actuation. Rotary pin actuation may be either clockwise or counterclockwise. A positive stop prevents



Eight reasons why Burroughs chose Teletype Printer for the new 220

ElectroData Division of Burroughs Corporation made extensive tests and comparisons before choosing a supervisory and off-line printer for their new, high-speed electronic data processing system—the Burroughs 220.

Here are the eight reasons for choosing the Teletype Model 28 Printer:

1 Reliability. In actual test, the Teletype Model 28 Printer ran continuously . . . more than 20 times as long as other equipment tested.

2 Parallel Input. The Printer accepts parallel input information—desirable since the output from the data-processor is parallel.

3 Coding Flexibility. Type boxes used in the Model 28 Printer may be interchanged quickly and easily to suit a variety of code requirements. This feature is unique with Teletype.

Any code may be made to accomplish any non-printing function in the printer or to actuate a transfer contact—by a simple change in the Stunt Box (exclusive with Teletype).

4 Speed. The Model 28 Printer meets the speed requirement of 100 words per minute.

5 Readability. Quick reading of the copy is easier because type box moves across a stationary platen—rests out of the way between characters.

6 Tabulating. The Printer is equipped with a horizontal tab which is fast and adjustable. It has, also, an adjustable "Form-Out" for indexing printing on next printed form.

7 Appearance. The Teletype Model 28 Printer is housed in a well-designed, attractive cabinet.

8 Quiet Operation. Operating noises are reduced to a minimum by the sound absorbing cabinet enclosure.

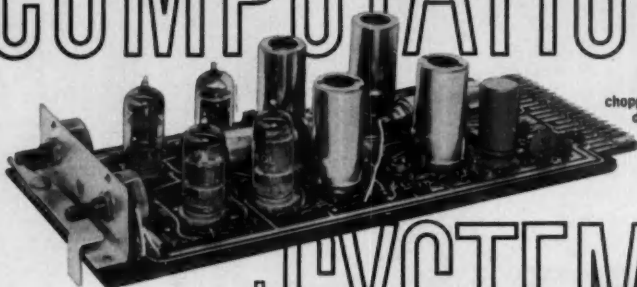
More Information. The Model 28 Printer is one of several units in the all-new Model 28 line of Teletype equipment. If you would like more information on these new units, write to Teletype Corporation, Dept. 22B, 4100 Fullerton Avenue, Chicago 39, Illinois.

TELETYPE[®]

CORPORATION

SUBSIDIARY OF *Western Electric Company* INC.

COMPUTATION



Model 3101
chopper-stabilized
dual amplifier

and SYSTEMS CONTROL

DONNER

Precision

Plug-in Amplifiers,

Function Generators,

Multipliers,

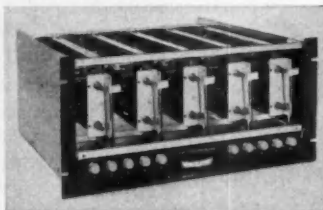
Power

Supplies

New Donner computer and control elements are designed to simplify the job of the analog systems engineer.

If you are interested in expanding the capacity of your analog computer, no matter what make or size, constructing a special purpose computer, or erecting an analog control loop, Donner analog systems components will perform a precision job at an economical price.

Typically, key specifications for the chopper stabilized amplifier shown above are dc gain in excess of 50 million; maximum offset of a unity inverter, less than $100 \mu\text{v/day}$; drift of unity integrator, less than $100 \mu\text{v/sec}$; phase shift of unity inverter, less than 0.5 degrees at 1 kc. Price of this dual amplifier is only \$230 or \$115 per channel. Even lower prices on quantity sales.



Donner plug-in amplifiers
in rack-mount configuration

Your nearby Donner engineering representative will be happy to supply you with complete applications data or you may write us here in Concord if you choose. Please address Dept. 082.

**DONNER SCIENTIFIC
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CONCORD, CALIFORNIA
Phone MUlberry 2-6161 Cable "DONNER"

CIRCLE 76 ON READER-SERVICE CARD

NEW PRODUCTS

damage that might otherwise result from excessive overtravel. Contacts are rated for 10 amp at 125 vac or 5 amp at 250 vac.—Cherry Electrical Products Corp., Highland Park, Ill.

Circle No. 226 on reply card

PLUS . . .

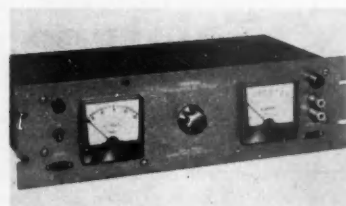
(227) A series of crystal can relays with sensitivities as low as 25 mw in the spdt types has been announced by the Electronics Div. of the Iron Fireman Mfg. Co., Portland, Ore. . . .

(228) Fawick Airflex Div. of the Fawick Corp., Cleveland, Ohio, is distributing a new system of press controls designed to provide anti-repeat protection on presses, shears, conveyors, and other industrial equipment. . . . (229)

An interchangeable coil is featured in a new 25-amp heavy-duty power relay developed by Guardian Electric Mfg. Co., Chicago, Ill.

Circle No. 227, 228, or 229
on reply card

POWER SUPPLIES



PANEL-MOUNTED

Photo shows one model in a new series of regulated variable ac power supplies. Units feature high-quality waveform, 2-percent voltage and current meters, front and rear output terminals, and built-in short-circuit protection. Uses include testing of diodes, transformers, chokes, and other components, instrument calibration, over- and under-voltage testing, and critical photography.

Characteristics:

Ratings: 60 to 500 va
Currents: 3 to 20 amps
Voltage: 0 to 130 volts, all units
Voltage regulation: within 1 percent
Harmonic distortion: under 3 percent
Response time: under $1\frac{1}{2}$ cycles
—Nutron Mfg. Co., Inc., Staten Island, N. Y.

Circle No. 230 on reply card

K (STANDARD)

For Aircraft,
Electronic, Instrument,
Military, Missile, Industrial
and Commercial Applications.

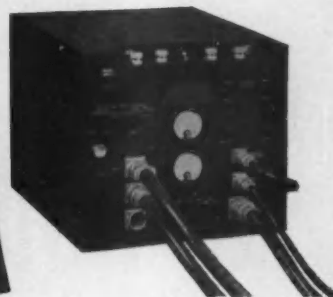


Standard K and RK...in straight and angle 90° plugs, wall mounting receptacles. Conduit and clamp entry types. 1 to 82 contacts in 213 different insert arrangements. 10-, 15-, 30-, 40-, 60-, 80-, 115-, and 200-amp. silver-plated brass contacts. High quality phenolic, melamine, and formica insulators. Cadmium-plated aluminum alloy shells. Flashover voltages: 1100 to 5000v 60cps ac rms.

connect
with
**CANNON
PLUGS**

APPLICATION

Application of R and RK connectors
on a recording oscillograph.



original aircraft, electronics, sound, and all-purpose line

KH, RKH (HERMETICALLY SEALED)

For Use Under Critical Pressure and
Leakage Conditions



Hermetically sealed connectors... with steel shells, steel contacts, and Can-seal glass insulators, fused to shell and contacts. True hermetic sealing. Electro tin plating over cadmium plate over copper flash provides highly receptive surface for soldering and corrosion resistance.

STEEL SHELL FIREWALL

For Open Flame Protection Against
High Temperatures



FW and FWR Cannon K Firewall Connectors... available in straight and angle 90° plugs, wall mounting receptacles. Inserts of phenolic or fireproof inserts of glass-filled materials. Crimp type contacts. Cannon made the first fire-wall connector and continues the leader in this important field.

RECORDER CONNECTOR

For Telephone "Beeper" Connectors



SK-M7-21C... Widely used on two lead-ing makes of telephone recorded connector units known as "beepers" because of the signal required by law in such recordings.

special acme thread • rugged construction • variety of coaxials • integral clamps

RK PLUG AND RECEPTACLE

For Flush or Semi-Flush Mounting



RK plug and pin assemblies are equipped with an external threaded coupling nut which is the reverse of the standard K series. Note, RK will not mate with K's.

RLKL and LKL (TV SWITCHING PANEL)

For TV Panel Switching



Quick Connect and Disconnect RLKL Plugs... designed for one-hand fast disconnect use on TV station program switching panels. Feature a quick coupling means. Latchlock secures plug to mated fitting (RLKL receptacle). Thumb pressure releases it.

K ACCESSORIES

Straight and Angle 90° Junction Shells,
Dust Caps, Bonding Rings, Gland Nuts,
Clamps, Dummy Receptacles



Featuring High Quality Materials and Workmanship... Junction shells are designed to protect, shield, and carry wires through walls, panels or bulkheads to conduit. Dummy receptacles hold and protect plugs when not in use.

cannon plugs • standard of quality for the industry

TBF-K

For Carrying Circuits Through Bulk-
heads



TBF-K Bulkhead Connectors... feature a double-faced construction allowing mating at both ends. Pin inserts. Single piece shell. Five insert assemblies available.

Other Cannon Series... Mil. Spec. "MS" (full line) — External Power Con-nectors — Switching Types — dc Solenoids — Guided Missile Launching Connectors — Miniatures and Sub-Miniatures.



See "K" Bulletin
for Engineering Data.



Please Refer to this Magazine or to Dept. 422

CANNON PLUGS

Where Reliability for Your Product Is Our Constant Goal

CANNON ELECTRIC COMPANY, 3208 Humboldt St., Los Angeles 31, California. Factories in Los Angeles; Salem, Massachusetts; Toronto, Canada; London, England; Melbourne, Australia. Manufacturing licensees in Paris, France; Tokyo, Japan. Contact our representatives and distributors in all principal cities. See your Telephone Yellow Book.

BENDIX ANNOUNCES NEW

15-AMP POWER TRANSISTOR SERIES

Now in production by Bendix are eight new 15-ampere power transistors capable of switching up to 1000 watts—and you can get immediate delivery on all eight types.

New in design, the transistors have a higher gain and flatter beta curve. The series are categorized in gain and voltage breakdown to provide optimum matching and to eliminate burn-out. Straight pins or flying leads can be supplied on request.

Ask for complete details on this new Bendix transistor series... and on the complete Bendix line of power rectifiers and power transistors. Write SEMICONDUCTOR PRODUCTS, BENDIX AVIATION CORPORATION, LONG BRANCH, NEW JERSEY.

Current Gain at 10 Adc	Collector-to-Emitter Voltage Rating*			
	30	40	70	80
20-60	2N1031	2N1031A	2N1031B	2N1031C
50-100	2N1032	2N1032A	2N1032B	2N1032C

*Comparable collector-to-base breakdowns range 20-50% higher.

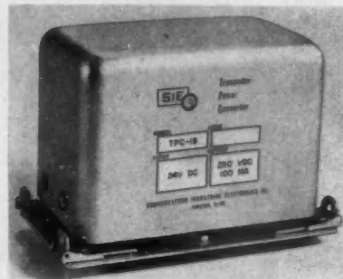
West Coast Sales and Service:
117 E. Providencia Ave., Burbank, Calif.
Canadian Affiliate: Computing Devices of Canada, Ltd.,
P. O. Box 508, Ottawa 4, Ont.
Export Sales & Service: Bendix International,
205 E. 42nd St., New York 17, N. Y.

Red Bank Division
LONG BRANCH, N. J.



CIRCLE 78 ON READER-SERVICE CARD
CONTROL ENGINEERING

NEW PRODUCTS



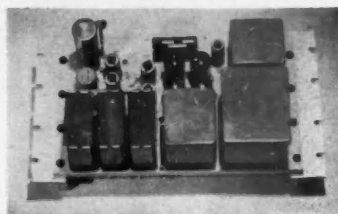
REPLACE DYNAMOTORS

Two new transistorized power supplies have been designed specifically to replace 14- and 28-volt dynamotors for powering airborne communication and navigation receivers. Both use a transistorized multivibrator circuit that is self-protected against overloads and shorts.

Characteristics:

Output: 250 vdc at 100 ma
Regulation: better than 10 percent
Efficiency: over 80 percent
Temperature range: minus 55 to plus 71 deg C
Altitude limit: 50,000 ft
—Southwestern Industrial Electronics Co., Houston, Tex.

Circle No. 231 on reply card



PRECISION FREQUENCY

With an input of 98 to 132 volts at 50 to 500 cps, this Type 2111F power supply provides a fixed frequency output in the 60-to-500-cps range with an error of less than 20 parts per million. Unit will deliver 50 watts of output power at any voltage from 0 to 115 volts. Operating temperatures may range from minus 50 to plus 50 deg C. It mounts on a 10-by-16-in. chassis and weighs 38 lb. — American Time Products, Inc., New York, N. Y.

Circle No. 232 on reply card

PLUS...

(233) A transistorized dc power supply, offered by Perkin Engineering Corp., El Segundo, Calif., provides 24



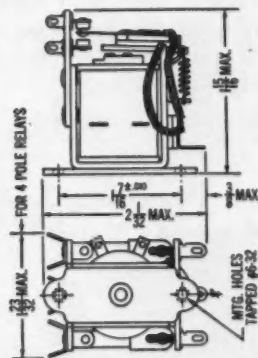
KL-A VERSATILE, RELIABLE, LOW COST P & B RELAY for communications and automation

ECONOMY and versatility distinguish our KL series relays. Contact arrangements are available up to 4 pdt in either AC or DC versions. Sensitivity of 100 milliwatts per movable arm is available.

Stationary contacts and terminals are mounted on a phenolic front of high dielectric strength, thus adding to the utility of the relay. Conveniently located terminals and easy-to-mount base greatly simplify installation on long production runs.

KL relays may be hermetically sealed or furnished in metal dust covers.

This is one of a "family" of fine P&B relays. Others, with similar configurations but various electrical and switching capacities, are shown below. Write or call for more information or see the complete P&B catalog in Sweet's Product Design File.



KL ENGINEERING DATA

GENERAL: Breakdown Voltage: 500 volt rms, 60 cycle between all elements standard 4 pole relay; 1500 volts rms, 60 cycle on special 3 pdt relay.

Temperature Range: -45°C. to +85°C.

Pull-In: Approx. 75% of nominal dc voltage.

Approx. 78% of nominal ac voltage.

Terminals: Pierced solder lugs for two #20 AWG wires.

Enclosures: Metal can 2 1/8" high x 2 3/8" long x 2 1/2" wide with octal plug or multiple solder header.

CONTACTS: Arrangements: up to 4 pdt.

Material: 1/8" dia. gold-flashed silver. (Others available.)

Load: 5 amps @ 115 volts, 60 cycle resistive loads.

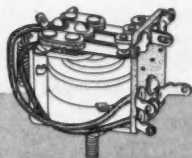
COILS: Resistance: 60,500 ohms max.

Power: 100 milliwatts per movable arm.

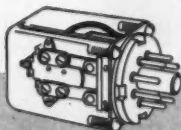
Duty: Continuous; coils will withstand 6 watts @ 25°C.

Voltages: up to 110 volts dc.
up to 230 volts ac.

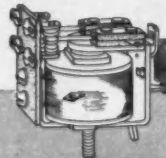
P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR



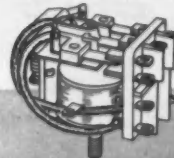
KR SERIES: SMALL, 5 AMP RELAY
Ruggedly constructed for long life and dependability. Available up to 3 pdt.



KCP SERIES: SENSITIVE 3 PDT RELAY
For plate circuit applications requiring low cost, sensitive relay. Polyethylene dust cover.



KT SERIES: ANTENNA RELAY
Insulated to minimize RF losses. Designed to switch 500 watts RF input to 300 ohm line.



KA SERIES: GENERAL PURPOSE
Compact, light-duty relay. U/L approved. Meets 1500 volts rms breakdown requirement.



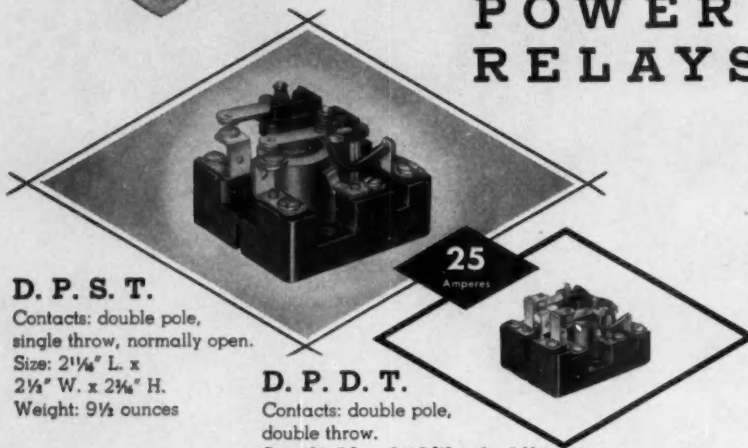
POTTER & BRUMFIELD INC.

PRINCETON, INDIANA • SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY

EVERYTHING UNDER CONTROL



with GUARDIAN POWER RELAYS



D. P. S. T.

Contacts: double pole,
single throw, normally open.
Size: $2\frac{1}{4}$ " L. x
 $2\frac{1}{2}$ " W. x $2\frac{3}{4}$ " H.
Weight: 9½ ounces

D. P. D. T.

Contacts: double pole,
double throw.
Size: $3\frac{3}{4}$ " L. x $2\frac{1}{2}$ " W. x $2\frac{3}{4}$ " H.
Weight: 11 ounces

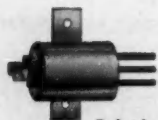
Interchangeable Coil Assemblies...

(No Solder Connections)

◆ Guardian's new double pole, *single* throw, normally open, 25-ampere power relay and the already popular double pole, *double* throw, 25-ampere power relay afford a wider latitude of control for motor starting, heater loads and such heavy duty industrial control applications as elevators, conveyors, electronic ovens, machine drives and automated systems. Both versions carry *interchangeable coil assemblies* that range in value from 6 v. A.C. to 230 v. A.C., or from 6 v. D.C. to 110 v. D.C. Each relay is ideally suited to experimental work, electronic design, prototype units and for meeting on-the-spot changes of electrical characteristics at any stage of design, development or production.

- Contacts rated at 25 amperes, continuous duty, at 230 v. A.C. with 75% power factor.
- Coils: 6 v. A.C. to 230 v. A.C. or 6 v. D.C. to 110 v. D.C.
- Coil insulation is electrical grade varnish impregnated and baked.
- Coil drain—approximately .080 amperes at 115 v., 60 cycles.
- Operating power 9.5 volt amperes, 60 cycles.
- Screw type terminals.
- Two hole mounting 8-32 clearance on $1\frac{1}{2}$ " centers.

Built to meet U/L specifications



Reloid



Powerloid



Series 155-A



Series 220

Write for Name of Your Nearby Industrial Distributor

GUARDIAN  **ELECTRIC**
MANUFACTURING COMPANY

1623-B W WALNUT STREET, CHICAGO 12, ILLINOIS

CIRCLE 80 ON READER-SERVICE CARD

CONTROL ENGINEERING

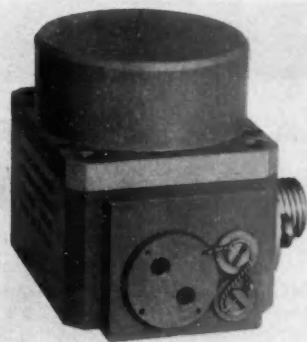
130

NEW PRODUCTS

to 32 volts at 10 amps with automatic current limiting. . . . (234) Mallory Battery Co., Cleveland, Ohio, is producing a new **mercury battery** only 0.300 in. in diameter for micro-miniature applications. . . . (235) New ac-dc **plug-in power supplies**, available with regulated and unregulated outputs to 300 vdc, are available from Consolidated Avionics Corp., Westbury, N. Y. . . . (236) Magnetic Amplifiers, Inc., New York, recently announced a new **static inverter** that uses transistors and a magnetic amplifier to convert 18 to 30 vdc to a 115-volt, 400-cps, single-phase source.

Circle No. **233, 234, 235, or 236**
on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



25 PERCENT SMALLER

Features of the new FC-30 servo-valves include a 25 percent volume reduction and a 20 percent weight reduction. Unit now measures 1.75 by 2 by 2.8 in. and weighs only 14.5 oz. Models available from stock cover flows from 0.15 to 13 gpm. Using MIL-0-5606 hydraulic fluid at 90 deg F and 3,000 psi supply pressure, the 4-gpm valve has a maximum internal leakage of only 0.9 gpm at the neutral position. Supply pressure operating range is 500 to 4,000 psi.—Cadillac Gage Co., Costa Mesa, Calif.

Circle No. **237** on reply card

USES RATE FEEDBACK

A completely integrated electrohydraulic servo system now in production provides an output velocity propor-

For centuries
angles have been read directly
..Now
they can be read photoelectrically
and the information
transmitted in digital form.
Write for Bulletin 8600-S.
W. & L. E. Gurley, Troy, N. Y.



The Gurley Shaft Position Encoder



Pat. No. 2816421
Other Pats. Pend.

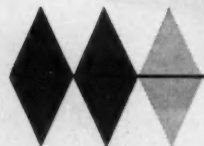
New extra compact 1/50 hp Servotran mechanical servo

This new, compact 1/50 hp Servotran is only two inches square. Although it is no larger than an ordinary gear box, it provides output shaft speeds infinitely variable over more than a 100 to 1 range, forward and reverse. It is ideal for use in automation equipment, recorders, machine tool feeds, etc.

The Servotran shifts from full speed forward to full speed reverse in only .05 second. Control shaft movement is only $\pm 10^\circ$ and control torque required is less than two inch ounces. Output torque constant. Efficiency between 85% and 95%.

This Servotran is shown with a direct control lever. It can also be furnished with a calibrated dial for manual control or with solenoids for electrical control.

For more information, write today to Humphrey Products Division, Dept. C-29, 3794 Rosecrans Street, San Diego 10, California.



Humphrey Inc.

HUMPHREY PRODUCTS
DIVISION

3794 ROSECRANS STREET, SAN DIEGO 10, CALIFORNIA

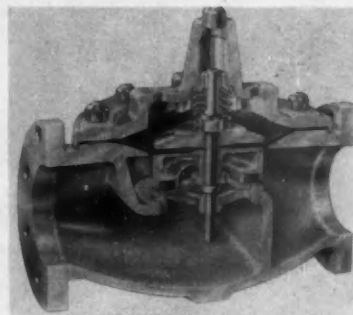
CIRCLE 82 ON READER-SERVICE CARD

CONTROL ENGINEERING

NEW PRODUCTS

tional to the input and time derivative of the input electrical command. Derivative computation is supplied by a unique hydromechanical rate-feedback network that measures and feeds back actuator velocity to the servo-valve flapper. One current application is the control of an auxiliary power supply on a gas turbine. —Hydraulic Research & Mfg. Co., Burbank, Calif.

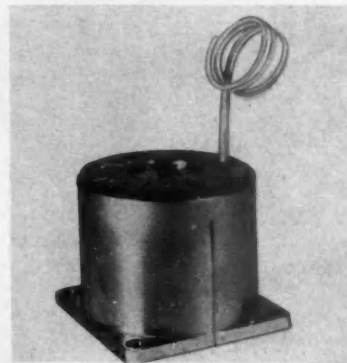
Circle No. 238 on reply card



IMPROVED DIAPHRAGM

Use of a newly developed, heat-resistant diaphragm material makes this versatile hydraulic valve suitable for continuous service at temperatures up to 250 deg F. Units are available in sizes from $\frac{1}{2}$ in. to 16 in. for such applications as water softeners, filters, boiler feed units, and waste-water disposal systems.—Automatic Valve Systems Co., Newport Beach, Calif.

Circle No. 239 on reply card



RAPID RESPONSE

This new high-speed solenoid completes its stroke in less than 20 msec. Designed to operate with a 24-lb load, it has an ambient temperature range

NEW HYDRAULIC FLOW CONTROL VALVE

*Calibrated
for Precision
Control*

HANNA Flo-Set 1000 VALVES

are used for controlling flow
of petroleum liquids, water
and synthetic hydraulic fluids.

Pressure to 1000 psi.

Sizes 1/4", 3/8", 1/2" and 3/4"

Temperatures -40° F to +250° F



3/8" VALVE
Actual Size
\$16.00

To meet the demands for precision control of hydraulically powered equipment, Hanna offers this new calibrated speed control valve. Flow can be accurately regulated from zero to desired rate by turning the adjusting sleeve. Once set to the desired flow rate the valve can be "locked". Calibrations assist in setting the valve to pre-determined flow rates.

The new Flo-Set 1000 Valves are the result of over 50 years of Hanna design and manufacturing experience in the field of fluid power. They are built to close tolerances with quality materials and like all Hanna products they are offered only after extensive laboratory testing and field experience. Their performance is guaranteed for the service specified.

Ask your Hanna Representative listed in your classified directory and Thomas' Register for complete information—or write us for details.

Hanna Engineering Works



HYDRAULIC AND PNEUMATIC EQUIPMENT... CYLINDERS... VALVES

1749 ELSTON AVENUE, CHICAGO 22, ILLINOIS

CIRCLE 83 ON READER-SERVICE CARD

FEBRUARY 1959

133

NEW VIBRATING CAPACITOR



A vibrating-reed type capacitance modulator for use in measuring currents as low as 10^{-16} amperes.

Long term stability for process control. Drift ± 0.2 millivolts per day, non-cumulative.

Write for
Catalog 523.



**STEVENS
INCORPORATED
ARNOLD**

7 ELKINS STREET
SOUTH BOSTON 27, MASS.

S/A-15

CIRCLE 84 ON READER-SERVICE CARD

134

CONTROL ENGINEERING

NEW PRODUCTS

of minus 65 to plus 160 deg F, and a voltage rating of 24 vdc at 78 deg F. At this temperature, coil resistance is 19.2 ohms. —Telecomputing Corp., Los Angeles, Calif.

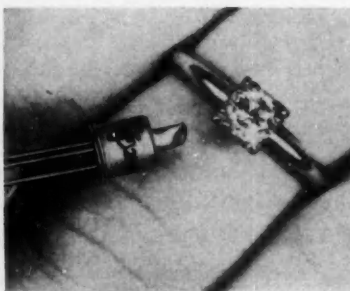
Circle No. 240 on reply card

PLUS . . .

(241) A permanent-magnet stepper motor, developed by American Electronics, Inc., Los Angeles, Calif., provides a minimum stepping rate of 90 pulses per sec in random pulse direction. . . (242) Bettis Corp., Houston, Tex., announces a new line of valve actuators that convert 3 to 15 psi instrument air to high torque operation for throttling or positioning plug valves, ball valves, and other 90-deg rotation devices. . . (243) Gates valves for handling liquid oxygen and other cryogenics at temperatures down to minus 320 deg F are now available from Koehler Aircraft Products Co., Dayton, O.

Circle 241, 242, 243 on reply card

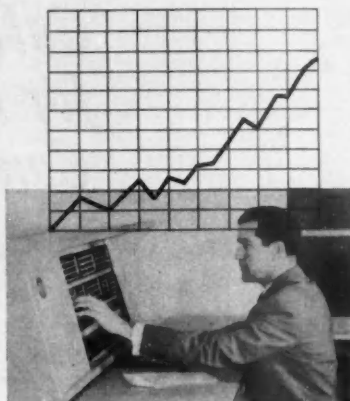
COMPONENT PARTS



HIGH RELIABILITY

Developed and first produced by Bell Telephone Laboratories, this type 2N559 ultra-high-frequency, diffused-base, germanium transistor is particularly well-suited for advanced missile and aircraft applications where reliability is a must. The device exceeds reliability specifications outlined in MIL T-19500A and offers switching speeds in the millimicrosecond range. Conservatively rated to dissipate over 150 mw in free air, it will operate at temperatures up to 100 deg C. —Texas Instruments, Inc., Dallas, Tex.

Circle No. 244 on reply card



COMPUTER SPECIALISTS GROW PROFESSIONALLY WITH BURROUGHS

Burroughs Corporation, ElectroData Division, has just completed the most successful sales year in its five-year history. In this dynamic, youthful organization new opportunities are constantly arising. For professionals who seek the advantages of a completely computer-centered company, in all its aspects, ElectroData Division has much to offer.

Openings exist in Pasadena in Product Planning, Applied Programming, Publications and Training, and in scientific and commercial applications.

In the field, throughout the U. S., there are openings for Application and Programming Specialists who are interested in being part of a sales operation, with all its variety, excitement and rewards.

If you feel you can meet the standards of this quality-conscious organization, and if you want to participate personally in one of the most stimulating business dramas of the 20th century, contact the nearest Burroughs-ElectroData office—or write to Professional Personnel Director in Pasadena.



Burroughs Corporation
ELECTRODATA DIVISION
PASADENA, CALIFORNIA

"NEW DIMENSIONS" in electronics and data processing systems

Announcing Epsco's **NEW**

DVOM

**ADVANCE IN
DIGITAL
VOLT-OHM
METERS**



FULLY TRANSISTORIZED
No Stepping Switches • No Relays



First in data control

● **VERSATILE** accurately measures both resistances and AC-DC voltages and counts external events, too! Directly drives printers, punches and memory storage units and can be directly used as a bi-directional tele-meter.

● **FAST** less than 2 millisecond reading time . . . up to 100 completely independent measurements per second for any system use.

● **EASY TO READ** in-line, in-plane visual display . . . lamp life up to 10,000 hours . . . numerals 1 1/8 inch high . . . automatic indication of polarity, decimal point and mode of operation

True dependability and versatility have at long last come to digital volt-ohm meters in EPSCO'S new DVOM. Fully transistorized . . . adjustment-free . . . no stepping switches or relays. Provides precise numerical measurement of AC-DC voltages, resistances . . . fast, accurate visual or printed quality control data . . . high-speed data acquisition for direct print-out or storage . . . remote indication and data transmission over a single line. Compact, lightweight, portable — also for rack-mounting. Write for Bulletin 95801, Epsco, Inc., Equipment Division, 588 Commonwealth Ave., Boston 15, Mass.; in the West: Epsco-West, 125 E. Orangethorpe Ave., Anaheim, California

DVOM price \$1,475

Ask for a demonstration.

New Modular Design IN PRESET COUNTERS ANY COMBINATION—Single or Dual 2-3-4-5-6 Decades



the **ERIE**

**INSTRU/MATION® Model 320 Series
Preset Digital Electronic Counters**

Applications—Industrial counting, sorting, batching, winding, packaging and other control functions.

Check these Features—

- ✓ **WIDE RANGE**—From 0 to 5,000 cps on manual; from 0 to 2,000 cps on automatic reset. Range from 1 to 999,999 counts.
- ✓ **SIMPLICITY**—2 or 3 Decade Modular plug-ins, pluggable control unit and accessories provide maximum flexibility, ease of maintenance, high reliability. Dependable glow tubes for scaling and display.
- ✓ **VERSATILITY**—Photo-cell input; variable contact closure time; relay latching for "hold"; remote or local reset; plug-in batching registers and dual presets available.
- ✓ **COMPACT, LIGHT WEIGHT**—The 4 decade unit is 6" x 12" x 13" and weighs 13 pounds. Other units in proportion.
- ✓ **ECONOMICALLY PRICED**—The Model 320 Series range in price from \$375.00 to \$650.00, F.O.B. Hawthorne, California.

Write for detailed information and prices on Model 320
and other ERIE Digital Instruments



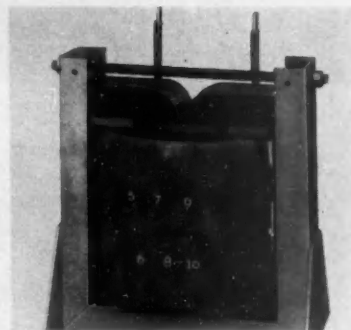
CIRCLE 86 ON READER-SERVICE CARD

NEW PRODUCTS

RUGGED AND RELIABLE

Four new alloy junction transistors feature a uniform 35-ohm input resistance for greater freedom in circuit design and construction. Said to be the first silicon p-n-p type for 1 to 4 Mc operation in severe environments, the units have collector voltages of 15 or 35 volts, depending on the model. This, plus a high current gain characteristic, permits a much broader application. Other features include low saturation resistance and a power rating of 150 mw.—Sperry Semiconductor Div., Sperry Rand Corp., South Norwalk, Conn.

Circle No. 245 on reply card



GAPLESS CORE

The Super Power 1290 Series, a new line of power magnetic amplifiers, features 18 standard sizes ranging from 500 va to more than 32 kva. A tape-wound gapless core permits a minimum of control ampere-turns and eliminates the irregular performance usually associated with air gaps. Manufacturer claims the new design provides more power-output per dollar.—Vickers, Inc., St. Louis, Mo.

Circle No. 246 on reply card

PLUS . . .

(247) A complete line of low-power transformers for remote control and signal circuits was recently announced by Anderson Controls, Inc., Franklin Park, Ill. . . . (248) Daystrom Pacific, Los Angeles, Calif., has upgraded its line of 1½-in. Squaretrim pots to suit high-temperature applications. . . . (249) Accuracies to within 0.005 percent are claimed by General Resistance, Inc., New York, for a new line of precision resistor networks designed for use in 400-cycle systems.

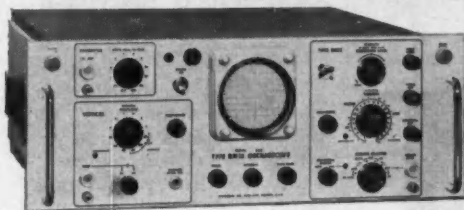
Circle No. 247, 248, or 249 on reply card

SMALL WIDE-BAND

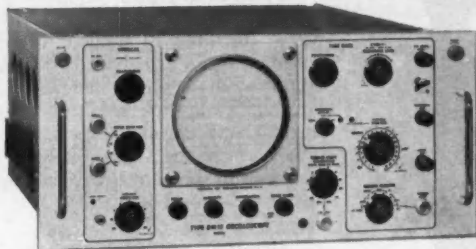


SCOPES

for RACK-MOUNTED installations



TYPE RM16 AND TYPE RM17
dc-to-10 mc, 3-inch crt, 7-inch rack height



TYPE RM15
dc-to-15 mc, 5-inch crt, 8 1/4-inch rack height

TYPE RM16 AND TYPE RM17

SIZE

7" high, 19" wide, 17 1/2" rack depth.
Slide-out mounting for servicing ease.

VERTICAL CHARACTERISTICS

Passband—dc-to-10 mc.
Risettime—0.035 μ sec.
Signal Delay—0.25 μ sec.
Sensitivity—0.1 v/div to 125 v/div, dc-coupled and ac-coupled
—0.01 v/div to 0.1 v/div, ac-coupled only. Twelve calibrated steps.

SWEEP RANGE

Calibrated—22 steps from 0.2 μ sec/div to 2 sec/div.
Continuously Variable—0.2 μ sec/div to 6 sec/div.
Magnifier—5 x.

TRIGGERING

Preset or manual stability control with amplitude-level selection, and fully-automatic triggering.

OTHER FEATURES

Amplitude Calibrator.
DC-Coupled Unblanking.
Electronically Regulated Power Supplies.
Type RM16—1.85-kv accelerating potential\$795
Type RM17—9-kv accelerating potential for easy
readability under conditions of high ambient light\$870

TYPE RM15

SIZE

8 1/4" high, 19" wide, 22 1/4" rack depth.
Slide-out mounting for servicing ease.

VERTICAL CHARACTERISTICS

Passband—dc-to-15 mc.
Risettime—0.023 μ sec.
Signal Delay—0.25 μ sec.
Sensitivity—0.05 v/cm to 20 v/cm in nine calibrated steps,
0.05 v/cm to 50 v/cm continuously variable.

SWEEP RANGE

Calibrated—22 steps from 0.2 μ sec/cm to 2 sec/cm.
Continuously Variable—0.2 μ sec/cm to 6 sec/cm.
Magnifier—5 x.

TRIGGERING

Preset or manual stability control with amplitude-level selection, and fully-automatic triggering.

OTHER FEATURES

4-KV accelerating Potential.
Amplitude Calibrator.
DC-Coupled Unblanking.
Electronically Regulated Power Supplies.

Price, Type RM15\$825



The need for high performance in a rack-mounted oscilloscope can be satisfied without excessive space requirements. Three standard Tektronix Oscilloscopes meet stringent performance demands, although their mechanical designs represent good space economy. If the main specifications of any of these instruments indicate a possible solution to your problem, please call in your Tektronix Field Engineer for the complete story.

Tektronix, Inc.

P. O. Box 831 • Portland 7, Oregon

Phone CYpress 2-2611 • TWX-PD 311 • Cable: TEKTRONIX

TEKTRONIX FIELD OFFICES: Albion, L.I., N.Y. • Albuquerque • Atlanta, Ga. • Bronxville, N.Y. • Buffalo • Cleveland • Dallas • Dayton • Elmwood Park, Ill. • Endwell, N.Y. • Houston • Lathrup Village, Mich. • East Los Angeles • West Los Angeles • Minneapolis • Mission, Kansas • Newtonville, Mass. • Orlando, Fla. • Palo Alto, Calif. • Philadelphia • Phoenix • San Diego • St. Petersburg, Fla. • Syracuse • Towson, Md. • Union, N.J. • Washington, D.C. • Willowdale, Ont.

TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics, Portland, Oregon.; Seattle, Wash.; Hytronic Measurements, Denver, Colo.; Salt Lake City, Utah.

Tektronix is represented in 20 overseas countries by qualified engineering organizations.

SPECIAL MODEL

Type R516—Two-unit model of the Type RM16 with identical electrical specifications. Dimensions—Indicator unit: 7" high, 19" wide, 11 1/2" deep, Power Supply: 7" high, 19" wide, 5 1/2" deep.

Price, Type R516\$850

Please check with your Tektronix Field Engineer for delivery schedule on this model.

prices f.o.b. factory

Fail-Safe Regulator Ends Overheat Dangers!



AND
PROVIDES
PERFECT CONTROL
FOR

- LIQUIDS
- AIR
- GASES

This Series 1006 Fulton Sylphon® Safety Temperature Regulator has a built-in monitor that prevents damage to products in process due to sudden overheating caused by failure of thermostatic unit. Should corrosion, vibration or other accidents cause loss of the thermostatic charge, the control valve assumes "safe" position automatically.

Higher sensitivity, greater power, longer life, trouble-free operation assured by large two-ply seamless Sylphon Bellows. Completely self-powered. Sizes 1/4" thru 4"; single- or double-seated and three-way valves. Teflon chevron "life-time" valve stem packing ends leakage... provides smoother control... requires no lubrication.

Regulator for liquids shown above. Also available with fin type bulb for controlling air or gases.

For complete information, write for Bulletin D-CW



Robertshaw-Fulton

CONTROLS COMPANY

FULTON SYLPHON DIVISION • Knoxville 1, Tennessee

CIRCLE 88 ON READER-SERVICE CARD

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CONTROL ENGINEERING

WHAT'S NEW

(Continued from page 48)

has an international outlet. General Mills began designing and making heavy-duty power manipulators and reactor-fuel-charging systems in 1948.

CEC-Elliott Agreement Covers the Commonwealth

A new licensing agreement between Consolidated Electro-dynamics Corp. and Elliott-Automation, Ltd., of England, permits the latter to manufacture and market certain CEC-designed analytical and control instruments in all countries of the British Commonwealth except Canada, and to supply CEC's own wholly-owned German subsidiary in Frankfurt-Main.

The instruments named in the agreement include analytical and process-control mass spectrometers, chromatographs, moisture monitors, refractometers, and oxygen analyzers. Elliott anticipates selling them largely to companies in the petroleum, chemical, and petrochemical industries.

COMPANY STATEMENTS¹

Baird-Atomic ²	\$125,900 (+577%)
	\$6,744,800 (+1.5%)
Beckman ^{3, 4}	\$39,823,317 (+4%)
Collins Radio ⁵	\$1,936,197 (-12%)
	\$107,569,000 (-16%)
Consolidated	
Diesel	\$337,611 (+40%)
Electric ⁶	\$21,871,809 (-26%)
Dresser	\$9,882,000 (-47%)
Industries ⁶	\$225,264,000 (-18%)
Fischer & Porter ⁷	\$146,000 (-70.02%)
	\$15,228,000 (+5.6%)
Litton	\$3,700,000 (+105%)
Industries ⁸	\$83,000,000 (+196%)
W. L. Maxson ⁹	\$53,170 (-76%)
	\$15,185,233 (-23%)
Nuclear-Chicago ⁸	\$442,252 (+74%)
	\$3,851,078 (+45%)
Packard-Bell ⁸	\$1,002,593 (+42%)
	\$37,371,081 (+16%)
Reliance E&E ⁸	\$3,772,748 (-38%)
	\$70,591,510 (-26%)
Sanders	\$233,487 (-7.03%)
Associates ⁹	\$8,969,770 (+60.08%)
Siegler ⁹	\$1,125,930 (+16%)
	\$72,955,449 (+125%)
Universal	\$68,594 (-83%)
Winding	\$14,316,622 (-4.8%)

¹ First figure is net earnings, second is net sales; percentages reflect increases or decreases with respect to preceding fiscal year. ² Fiscal year ending Sept. 30, 1958. ³ Fiscal year ending June 30, 1958. ⁴ Net earnings negative; only net sales shown. ⁵ Fiscal year ending July 31, 1958. ⁶ Fiscal year ending Oct. 31, 1958. ⁷ Fiscal year ending April 30, 1958. ⁸ Fiscal year ending Aug. 31, 1958.

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

HIGH SPEED STATIC SWITCHING (at half the price)!

Sylvania Electric Products Co. engineers have just replaced an electronic relay, two small mechanical relays, a limit switch, and a separate power supply with a single CONTROL switching reactor which costs only half as much! They did it by taking advantage of the multiple windings on a CONTROL switching reactor—equipment which, because of its static operation, never wears out. Seems a high speed assembly operation on one of Sylvania's complex, highly automated vacuum tube production machines calls for a magnetic clutch to drive an index table. The clutch orients the work part by rotating it until current flows through two properly located contacts. Our CONTROL switching reactors not only cut costs in half, but do a job that the relays couldn't do: provide the ultra high speed signal necessary for proper switching in the automated assembly. *It worked so well Sylvania said, "I'll be switched!" We said, "With a 10,000 to one switching ratio, and ratings of 15, 75, 150 and 300 VA, most anything for control can be!"*

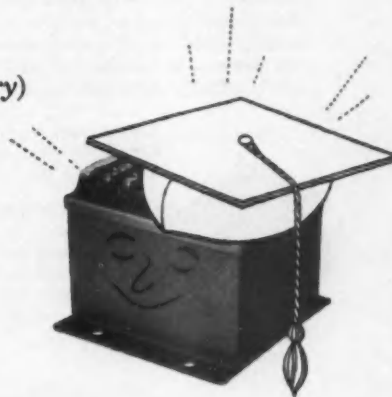


ONCE UPON A TIME . . . (time delay, that is)

Versatile, we are too! The same type of CONTROL switching reactors that work so well for this high speed switching also are used by Sylvania engineers to eliminate production breakdowns caused by relay failures in time delay circuits. Many pneumatic time delay relays on their production machines were dying young (three months of age or less). CONTROL switching reactors (which, naturally, never wear out) not only have no moving parts, but do a dandy job with time delay relaying, easily handling 6,000 closures per hour. Sylvania happily expects its CONTROL reactors to last twenty years. *"Right now," Sylvania says, "we're not too worried about what will happen after that." Need you be any more worried than they?*

LOGIC, MY DEAR WATSON (. . . is elementary)

Our educated switching reactors are masters at logic—the kind that gets built into automatic control operations. AND, OR, NOT, MEMORY and TIME DELAY—all are built into these high IQ reactors. By employing several isolated control windings, one reactor can translate many inputs (from push buttons, limit switches or other reactors, for instance) to any logic needed to switch very appreciable loads. And are they easy to use! Order standard units right from the catalog. You need no high falutin' systems engineering or auxiliary hardware (single purpose logic units, preamplifiers or transformers). *No wonder logical people order our logic-providing switching reactors. Can we send complete details to you?*



Reliability begins with

CONTROL

A DIVISION OF MAGNETICS, INC.

Dept. CE-54, BUTLER, PENNSYLVANIA



... a completely new pressure pickup family

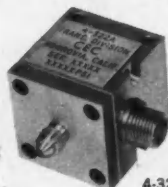
Inside the stainless steel housings of CEC's new unbonded strain-gage pickups is a completely new sensing element. This is the "interleaved" spring ... compactly constructed with two four-legged springs and two sets of windings intermeshed within a stainless steel ring. Movement of the pickup diaphragm causes extension of one set of windings and relaxation of the other. The change in resistance results in an electrical output directly proportional to displacement. With this element, all members of the "4-320" family offer these outstanding specifications:

Linearity and Hysteresis: 1% of full scale
Zero Shift: 0.01% of full scale per degree F
Sensitivity Shift: 0.01% of full scale per degree F



4-324

Type 4-322A measures differential pressures from ± 7.5 to ± 50 psi. Gage and absolute measurements are made with the 4-323MC in ranges up to 2000 psi and with the 4-324 in ranges to 5000 psi. For complete details, call your nearest CEC sales and service office, or write for Bulletin CEC 1617-X3.



4-322A



4-323 MC

Transducer Division

CEC

CONSOLIDATED ELECTRODYNAMICS/300 n. sierra madre villa, pasadena, california

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

CIRCLE 90 ON READER-SERVICE CARD

140

CONTROL ENGINEERING

WHAT'S NEW

Army Keeps Redstone

But the Jet Propulsion Laboratory goes to the National Aeronautics & Space Administration in a compromise spurred by Presidential order.

It is no longer news that the dispute over who shall operate Redstone Arsenal and the Jet Propulsion Laboratory (CtE, Dec., p. 45) has been resolved by compromise. Here are the highlights of the Presidential order of Dec. 3, which allows the Army to retain control of the arsenal and its 2,000 space scientists, and transfers JPL to the new National Aeronautics & Space Administration:

1. *What it means to the Army.* The Army has lost JPL, but has kept control over those JPL projects that are specifically military in nature and are expected to be phased out in 1959. These include the Sergeant guided missile program, special intelligence investigations, secure communications research, and aerodynamic testing and research.

If this work is not phased out this year, it may be completed by direct Army contract or through contract with NASA; either way, there will have to be mutual agreement between both organizations.

In addition, the Army will make available to NASA a portion of its Ballistic Missile Agency at Huntsville, Ala., an element of the Army Ordnance Missile Command. NASA will have the right to request the services, in a consulting capacity, of key AOMC personnel, and may also:

- place specific orders for projects directly with AOMC, with, of course, the funds for their accomplishment; full responsibility for fulfillment of these projects will be in the hands of AOMC

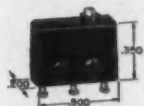
- keep a small staff in residence at AOMC, to provide a continuing exchange of information on all projects assigned to this command

- request that the Army's own prime and subcontractor facilities be used in projects funded by NASA, and that they be made available through identical procurement channels and special authorities

2. *What it means to JPL.* Cal Tech will continue to administer this laboratory, but projects to be undertaken by it will display a definite shift in intent, away from weapons and toward a peaceful conquest of space. This will probably entail some sort of personnel



MICRO SWITCH Precision Switches



ACTUAL SIZE

More news about the "SX" miniaturized subminiature switch

New actuators add to versatility of "SX" Series

Two of the auxiliary actuators for the "SX" are shown below. Others, not shown, are pivoted lever and pivoted roller lever variations. All are made of stainless steel.



LEAF ACTUATOR



ROLLER LEAF
ACTUATOR

The new "SX"—smallest precision snap-action switch—offers a new kind of answer to switching problems involving space, weight, and reliability. Here are some of the reasons:

SIZE (of case): .500" x .200" x .350" high—ten to the square inch.

WEIGHT: 1 gram . . . 28 switches to the ounce.

ELECTRICAL RATING: 28vdc: 7a. resistive, 4a. inductive-sea level; 2.5a inductive-50,000 ft.; 4a. motor load, 24a. max. inrush. 115/230 vac: 5a. resistive, 15a. max. inrush.

Other useful and newsworthy features of this remarkable switch include these:

Mechanical life is in the millions of operations.

The case of the "SX" has two through holes that will accept #2 screws. One hole is slightly elongated to facilitate mounting.

The "SX" operates dependably in temperatures from -65° F. to +250° F.

Operating force is controlled and predictable within 3 oz. to 5 oz. limits.

Terminals are integrally molded.

Special plating on terminals improves ease of soldering.

The normally-open and normally-closed terminal-contact inserts are solid silver and in one piece for maximum conductivity and heat dissipation.

For more information about this important switch, ask for Data Sheet 148.

MICRO SWITCH . . . FREEPORT, ILL.

A division of Honeywell

In Canada: Honeywell Controls Limited, Toronto 17, Ontario



Honeywell

MICRO SWITCH PRECISION SWITCHES

save valuable engineering time

HEATH *Electronic Analog Computer Kit*

"In the college classroom, or "on the job" in industry, the Heathkit Analog Computer solves physical or mechanical problems by electronic simulation of conditions. Full kit **\$945⁰⁰**



This advanced "slide-rule" is a highly accurate device that permits engineering or research personnel to simulate equations or physical problems electronically, and save many hours of involved calculation.

Ideal for industry, research, or instructional demonstrations. Incorporates such features as:

- 30 coefficient potentiometers, each capable of being set with extreme accuracy.
- 15 amplifiers using etched-metal circuit boards for quick assembly and stable operation.
- A nulling meter for accurate setting of computer voltages.
- A unique patch-board panel which enables the operator to "see" his computer block layout.

Because it is a kit, and you, yourself, supply the labor, you can now afford this instrument, which ordinarily might be out of reach economically. Write for full details today!

save money *with* HEATHKITS

Now for the first time, the cost of this highly accurate, time and work-saving computer need not rule out its use—You assemble it yourself and save hundreds of dollars.

FREE CATALOG also available describing test equipment, ham gear, and hi-fi equipment in kit form. Write for your copy today!



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A Subsidiary of Daystrom Inc.

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FOLDER**



Get the complete computer story from this four-page folder, available free!

CIRCLE 92 ON READER-SERVICE CARD

WHAT'S NEW

realignment, for as things stand now, 55 percent of the laboratory's 2,300 scientists and technicians are working on the Sergeant program alone. Still, it is doubtful that personnel will grow in number.

More work on guidance and liquid propellants lies ahead for JPL; in addition, it has been alerted for a deep space probe study project said to cost between \$1 and \$1.5 million.

3. *What it means to NASA.* This agency has estimated that if it were to develop its own facilities for nonmilitary space projects, it would have to invest more than \$70 million (the JPL plant costs more than \$55 million) and would have to recruit a supporting staff of between 2,000 and 3,000. All this would take from three to four years.

Beckman Gives Employees Option on 50,000 More Shares

Management of Beckman Instruments, Inc., has received shareholder approval of a plan to increase restricted stock options for employees by 50,000 shares, or from 75,000 to 125,000 shares. Originally approved in 1954, the plan is said to have been effective in attracting and retaining key personnel.

Environmental Engineers Form Chapter on Coast

The Institute of Environmental Engineers has formed a new West Coast chapter "to effect complete interchange of ideas and information pertaining to environmental testing and related fields". The first president of the new chapter is William H. Grumet, manager of American Laboratories, an environmental testing lab of American Electronics, Inc.

Hoffman Laboratories Buys the First Burroughs 220

Burroughs Corp. has delivered its first 220 electronic data processing system. Purchaser was the Hoffman Laboratories Div. of Hoffman Electronics Corp. The \$800,000 intermediate-scale computer is a digital system with a magnetic core memory. It performs 480,000 operations per min, files up to 600 million characters of information, and produces any record in seconds for automatic processing. It is now in volume production at the ElectroData Div. in Pasadena, Calif.

AiResearch centralized air data computing system...



on Navy's new McDonnell F4H-1

...supplying the following major airplane subsystems: Autopilot, Air Induction, Armament Control, Navigation, Surface Controls, Cockpit Indication and Pneumatic Static Pressure Correction.

The AiResearch centralized air data computing system integrates pneumatic, electronic, electrical and mechanical components on one of the Navy's fastest jets. It senses, measures, and automatically corrects all air parameters affecting flight. It supplies air data information to the pilot and all major airplane subsystems.

This centralized combination of transducers, computers and indicators is the

most complete air data computing system ever devised. It enables aircraft to operate at maximum efficiency continuously.

Eliminating duplication of components, the AiResearch centralized air data computing system cuts down space and weight requirements over decentralized systems by many times. Its principal functions: angle of attack, true static pressure (electrical and pneumatic), true air speed,

true Mach, altitude, rate of climb, total temperature, dynamic pressure and altitude and Mach error.

AiResearch has been the leader in the development of centralized computing systems. The F4H-1 installation is the first, single package air data computer possessing completely interchangeable, modular construction.

Your inquiries are invited.



ENGINEERING REPRESENTATIVES: AIRSUPPLY AND AERO ENGINEERING, OFFICES IN MAJOR CITIES

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

CIRCLE 93 ON READER-SERVICE CARD

FEBRUARY 1959

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AIRPAX

CHOPPER

AIRPAX TYPE 371



AVAILABLE IN PLUG-IN
OR BRACKET MOUNT

The Airpax type 371 chopper is designed to provide reliable operation under extreme conditions of shock and vibration. Its center pivoted armature permits it to function during vibrations of 15 G amplitude over a frequency range of 10 to 2500 CPS, with less than 10 degrees of contact derangement. Mechanical shocks of 50 G in any plane will not damage this chopper.

Drive is 6.3 volts, 400 CPS, and operating temperature range is from -65°C to 125°C . Hermetically sealed, the type 371 is operable in relative humidities to 100%. Information signals up to 100 volts DC at a maximum current of 2 ma, can be converted to a 400 CPS modified square wave.



THE AIRPAX PRODUCTS COMPANY
Cambridge Division, Cambridge, Md.

CM 13

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CIRCLE 94 ON READER-SERVICE CARD
CONTROL ENGINEERING

WHAT'S NEW

IMPORTANT MOVES BY KEY PEOPLE

Orville Orbom Joins Epsco as an Assistant Vice-President

Orville E. Orbom, well-known to control engineers because of his work in applying the latest solid-state electronic techniques to the control of steel-making and steel-rolling equipment, has joined Epsco, Inc., as assistant vice-president of industrial marketing. Most recently Orbom was manager of the Electromechanisms Dept. of Allegheny Ludlum Steel Corp. Before that he was with Alcoa, where experience with nonferrous rolling problems started him thinking about solid-state electronic controls.

At Epsco, Orbom will take part in long-range marketing plans directed at the industrial field. His background in industrial applications of machine control and data processing equipment will assure him a key role in new product development and sales, and in helping familiarize potential customers with Epsco's capabilities. In addition, he will be in a position to assist in the design of industrial systems and equipment.

J. R. Townsend Heads American Standards Group

The new president of the American Standards Association is J. R. Townsend, special assistant in the office of the assistant secretary of defense for R&D. He succeeds H. Thomas Hollowell Jr., president of Standard Pressed Steel Co. of Jenkintown, Pa., who has held the top post for three years, maximum under the ASA constitution.

Townsend is a past president of the American Society for Testing Materials. Before taking his government position in 1957, he was director of materials application engineering for Sandia Corp. ASA, a federation of 122 technical societies and trade associations, is the national coordinating body and clearinghouse for voluntary engineering, industrial, safety, and consumer standards in the U.S. It represents U.S. interests in international standards work.

Other Important Moves

L. S. Preston has left Electronic Engineering Co. of California, where he was chief engineer, to join Space Tech-

THE DIVISIONS OF THOMPSON RAMO WOOLDRIDGE INC.



RAMO-WOOLDRIDGE

While it is now a division of **Thompson Ramo Wooldridge Inc.** instead of a separate corporation, **Ramo-Wooldridge** remains an integrated organization for research, development, and manufacture of electronic systems for military and commercial applications. R-W's military work is covered by thirty-four contracts with the Army, Navy, Air Force, and other government and industrial organizations. These support a broad technical and—in some cases—manufacturing program in such varied fields as Electronic Reconnaissance and Countermeasures; Microwave Techniques; Infrared; Analog and Digital Computers; Air Navigation and Traffic Control; Antisubmarine Warfare; Electronic Language Translation; and advanced Radio and Wireline Communication.

In the commercial field, the well-known RW-300 industrial process control computer and associated equipment—the basis of the expanding business that **The Thompson-Ramo-Wooldridge Products Company** is doing with process industries—was developed and is manufactured by the Ramo-Wooldridge division.

Men, machines, and manufacturing know-how from other TRW divisions will be added as needed to build up the growing production strength of the Ramo-Wooldridge division. In other ways, too, the availability of the special skills and facilities of the rest of the corporate family will broaden the services R-W can offer to its customers. However, R-W's major systems work will continue to be done in an organizational framework that brings the engineering and manufacturing groups into close-knit project teams in the division's own integrated development and manufacturing facilities in both Los Angeles and Denver.

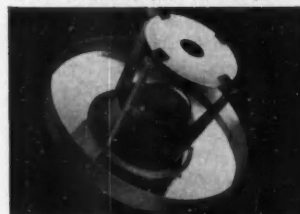
Ramo-Wooldridge is production-oriented in the sense that its end objective is the manufacture and sale of equipment. However, because of the highly technical nature of its product lines, the R-W division will continue to give unusual emphasis to maintaining a high degree of professional scientific and engineering competence.



The completely transistorized RW-30 airborne digital computer has a volume of 4.19 cu. ft. and weighs only 203 lbs., including power supply



Ramo-Wooldridge is responsible for advanced electronic sub-systems development for application with both current and projected missile programs



Important infrared "search and track" equipment is now being developed by Ramo-Wooldridge for applications in modern U.S. Military aircraft



R-W is one of the major participants working with the Boeing Airplane Co. Systems Management Office on the U.S. Air Force Dyna-Soar project



New type of radar data processing system developed by R-W materially increases the capabilities of ground defense radar



The RW-300 digital control computer has broad applications in automatic process control, data reduction and test facility operation



Systems are being developed for the ground processing and interpretation of photographic and other data collected by aerial reconnaissance devices



The Military and Ramo-Wooldridge are studying the use of automatic data processing techniques



In research laboratory studies at Ramo-Wooldridge, electrically-charged particles are contained and supported in a vacuum by an alternating electric field



Thompson Ramo Wooldridge Inc.

MAIN OFFICES
CLEVELAND 17, OHIO
LOS ANGELES 45, CALIFORNIA

AC travels in strange ways. It may come rippling in on a sine, jog along a sawtooth, pulse up and down a square or stutter over a distorted wave.

Only if it arrives on sine can you be reasonably sure of root mean square readings on the conventional panel meter, an instrument which senses average voltage and is calibrated to show rms.

Beckman Expanded Scale AC Voltmeters, however, provide direct rms readings on all wave forms, and for a very simple reason. Thermal elements used in the expansion network operate as a function of heat, and that's just what rms is... the heat value of an AC voltage.

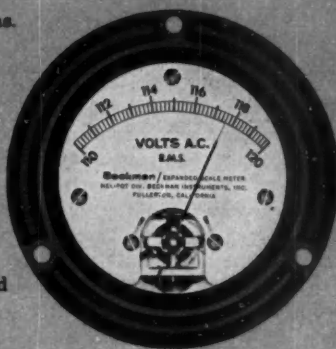
Add reliable rms to other exclusive advantages of the Beckman expanded scale panel voltmeter:

Accuracies to the fraction of a volt...reading resolutions to hundredths of a volt!

And you will know a volt when you see one.

Helipot offers you hundreds of models...either AC or DC...commercial or ruggedized...in a variety of shapes, sizes and voltage ranges. Need color coding, special ranges, assemblies? Yours for the asking. Send for data file G-24.

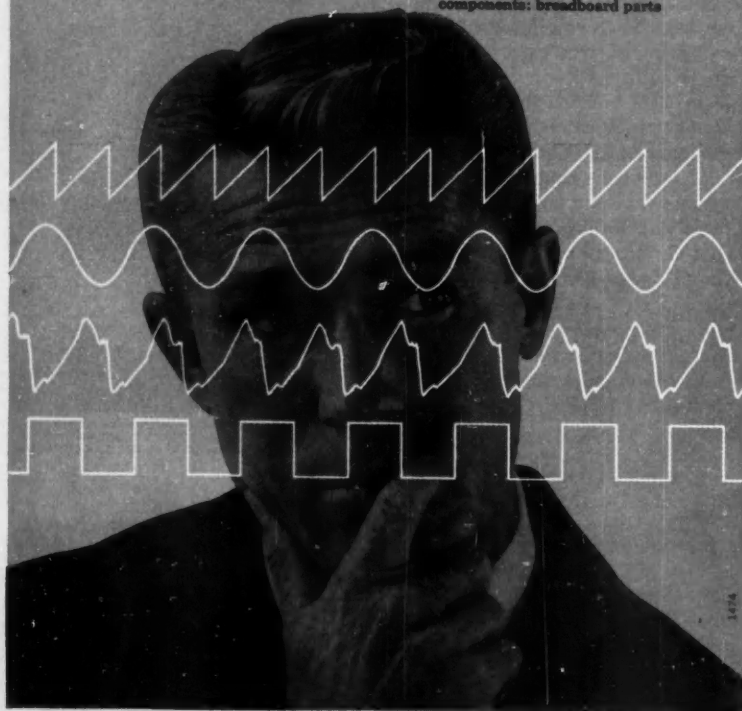
Do you
know a volt
when you
see one?



Beckman® Helipot®

Helipot Division of
Beckman Instruments, Inc.
Fullerton, California
Engineering representatives
in 20 cities

potentiometers: dials; delay lines
expanded scale meters: rotating
components: breadboard parts



CIRCLE 96 ON READER-SERVICE CARD

WHAT'S NEW

nology Laboratories. His successor is **Don R. Proctor**, assistant chief engineer since 1955. Preston joined the company in 1949, Proctor in 1951.

The new chief development engineer (special area: Defense Dept.) of Control Instrument Co. is **David R. Greenberg**, formerly head of the CI Co.'s defense and general engineering section. He joined the firm in 1952.

Donald G. Wilson has relinquished his duties as associate director of research and advanced development for Stromberg-Carlson to become general manager of Stromberg-Carlson-San Diego, the West Coast facility of the company's Electronics Div. Wilson's predecessor at San Diego is **Harold P. Field**, named director of marketing for the same division. Before joining Stromberg-Carlson in 1955, Wilson served the electrical engineering field primarily as an educator. He taught at Rensselaer, MIT, and the University of Kansas, headed the latter's Dept. of Electrical Engineering.

Robertshaw-Fulton Controls Co. has named **George Schatzman** director of the Fluid Controls Dept. of the Aeronautical & Instrument Div. He will be in charge of design and development of special flow devices for air and ground-support equipment.

The new director of engineering for Sierra Electronic Corp., Menlo Park, Calif., is **Sidney Frankel**, formerly senior staff scientist in Hughes Aircraft's Airborne System Laboratory. He has also been with Litton Industries, IT&T, and Eclipse Aviation Corp., among other firms. At Sierra, Frankel will coordinate R&D work connected with new products.

Jules Mersel, who has had a decade of experience applying his knowledge of mathematics, computers, and computer programming to the missile and atomic energy industries, has been named manager of the Data Processing & Operations Dept. in Space Technology Laboratories' Computation & Data Reduction Center. He joined STL in 1956.

Chicago Aerial Industries has appointed **Wayne Johnson** director of engineering. He will coordinate the expansion of Chicago Aerial's R&D facilities for missile systems and avionics under one executive office. At Lear, Inc., Johnson headed several aeronautical and flight control programs.

Harry W. Middlecoff, formerly an engineering group leader with North American Aviation's Autonetics Div., has been appointed chief engineer of Dressen-Barnes Corp., Pasadena manufacturer of power supplies.

One of these
handy prepaid
post cards
will bring you
detailed information

IMPORTANT: Circle key numbers below and mail before May 1, 1959

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
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6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

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201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
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207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
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2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
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8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

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201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
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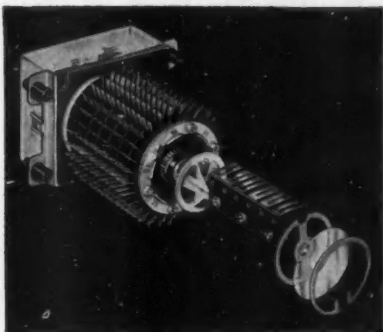
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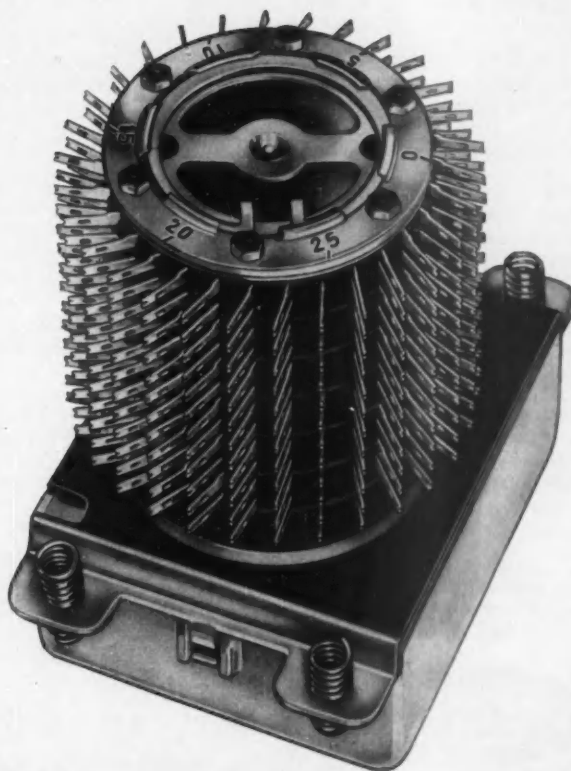
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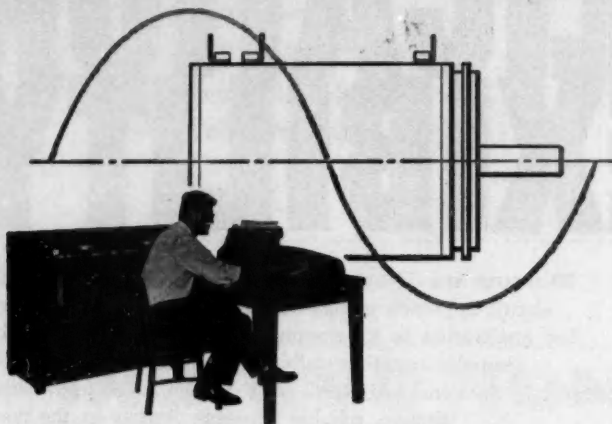


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BULLETINS AND CATALOGS

(300) **WIRE AND CABLE.** The Lewis Engineering Co. Catalog No. 458, 20 pp. Complete data and specifications on high-temperature wire, multiconductor cables, and thermocouple wire for aircraft, missile, and industrial applications. Also contains a page on insulated heating elements and various types of heating cable.

(301) **DATA REDUCTION.** Epsco, Inc. Bulletin, 4 pp. Outlines features and describes the operation of an advanced telemetry data reduction system that automatically converts PDM flight test data into direct digital computer format. Specifications listed cover inputs, outputs, accuracy, and power requirements.

(302) **LABORATORY MAGNET.** Varian Associates. Bulletin, 1 page. Offers a brief rundown on the operating characteristics and design features of a new 6-in. rotating laboratory magnet.

(303) **SOLID-STATE VOLTMETER.** Beckman/Systems Div. Bulletin 3018. Contains detailed information on the operation, circuit design, and specifications of a new, all-solid-state digital voltmeter that uses a unique comparison technique for high-speed readout.

(304) **DIAL THERMOMETERS.** U. S. Gauge Div., American Machine & Metals, Inc. Catalog 205, 12 pp. Describes the company's "Supertherm" line of indicating dial thermometers and accessory equipment. Graphs show the ranges of various filling mediums and a compact chart simplifies the selection problem.

(305) **DATA HANDLING.** Radiation, Inc. Short Form Catalog 1-58, 24 pp. Actually consists of six separate bulletins within a four-page folder. Equipment covered includes a regulated current and voltage standard, a telemetering dual mixer-monitor, a regenerative repeater, and two transmission-distortion measuring sets. Photos and circuit diagrams illustrate the text.

(306) **CONVERTER-INVERTERS.** Spectrol Electronics Corp. Data File 701, 4 pp. Small functional diagram illustrates the operation of one of four types of transistorized converter-inverters. Photos show various case styles and some of the construction details. Also lists standard and optional features.

(307) **DIAPHRAGM VALVES.** Hills-McCanna Co. Bulletin No. 115, 6 pp. Contains a number of helpful suggestions for selecting valves to be used in process piping systems. Photos illustrate typical process applications, while line drawings and an exploded view emphasize simplicity of operation and maintenance.

(308) **MOTOR-DRIVEN TIMERS.** Industrial Timer Corp. Bulletin No. 200, 4 pp. Describes important features of four different types of synchronous-motor-driven cam timers, each available in 13 models for a wide variety of industrial applications. Full-page chart covers 50 standard ratio gear and rack assemblies for time intervals up to 72 hours.

(309) **BIMETAL THERMOSTATS.** Stevens Mfg. Co. Bulletin 1000, 2 pp. Along with a description of operating principles and construction, this sheet lists available styles, ratings, and calibration data with respect to a complete line of

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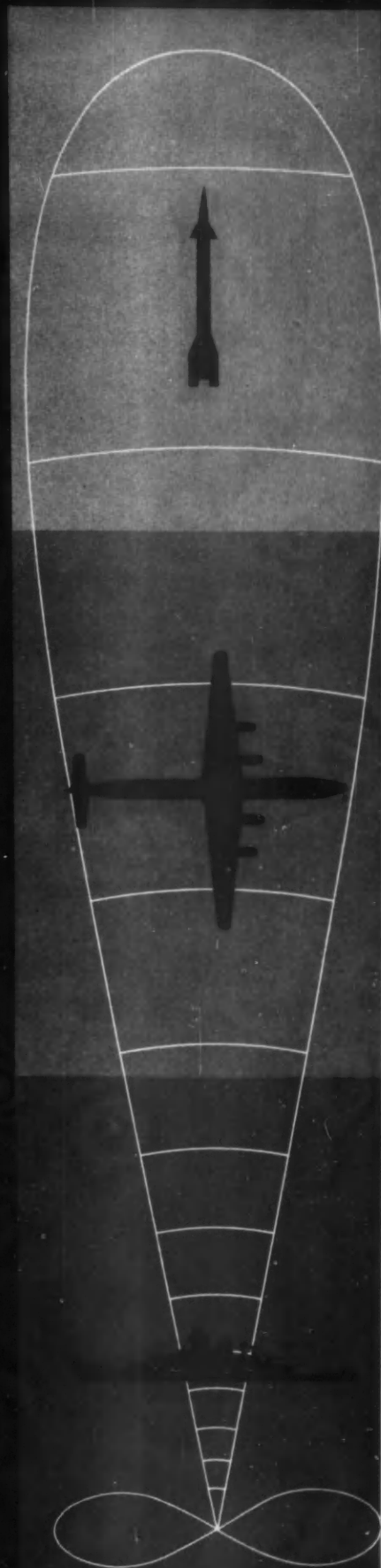
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Bulletins & Catalogs

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(310) **CORROSION RESISTANT.** Fischer & Porter Co. Spec. Sheets 12-1451T-1 to 5, 10 pp. Package covers a line of temperature indicators, controllers, and transmitters featuring corrosion-proof fiber glass cases and suitable for a range of minus 400 to plus 1,000 deg F.

(311) **ENCLOSED SWITCHES.** Micro Switch Div., Minneapolis-Honeywell Regulator Co. Catalog 83c, 20 pp. Provides complete details on metal-enclosed switches for industrial applications. Photos and line drawings cover over 99 different listings in nine housing groups.

(312) **MAGNETIC TAPE.** Minnesota Mining & Mfg. Co. Bulletin No. 36, 4 pp. Discusses the merits of a new "Scotch" brand precision tape reel designed to meet the critical requirements of instrumentation recording. Reviews such problems as flange clearance, hub design, and rigidity.

(313) **PRECISION COMPONENTS.** Ford Instrument Co. Brochure, 4 pp. Describes and illustrates a standard line of precision components for computers, instruments, and control systems. Specifications and performance data cover cams, synchros, mechanical differentials, oldham couplings, and low-inertia servomotors.

(314) **MINIATURE TERMINAL BOARDS.** Electronic Sales Div., Defur-Amsco Corp. Series MT Technical Bulletin, 2 pp. Handy reference sheet includes photos, dimension drawings, and a brief summary of electrical and mechanical ratings for a new line of four- and eight-turret miniature terminal boards.

(315) **PUMP DESIGN.** Pump Div., American Meter Co. Catalog 100. Provides a detailed description of the division's new Series 100 proportioning pumps as well as information about chemical feed pump-tank "package systems".

(316) **HEAVY-DUTY SWITCHES.** Micro Switch Div., Minneapolis-Honeywell Regulator Co. Catalog 84, 16 pp. Published as an aid to plant engineers and maintenance people as well as original equipment designers, this new bulletin contains complete details on three types of heavy-duty industrial limit switches.

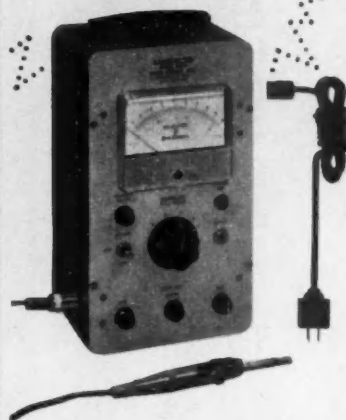
(317) **PRECISION POTS.** Bourns Laboratories, Inc. Specifications Summary No. 4, 4 pp. Summarizes key information on the company's line of Trimpot and Trimit lead-screw-actuated potentiometers. Specification table lists available resistances, terminal types, end-settings, power ratings, operating temperatures, and dimensions of the more popular models.

(318) **PRECISION GAGES.** Helicoil Gage Div., American Chain & Cable Co., Inc. Catalog DH-65, 32 pp. Information covers data on gage movement, types of systems, adjustments, and applications. Recommended specifications also included.

(319) **WEIGHT RECORDING.** Richardson Scale Co. Product Data Sheet 5805, 2 pp. Tells how to get precise inventory records automatically, with the aid of a Richardson Inventory Counter and Totalizer. Photo and isometric drawing illustrate its application to an actual feeding and proportioning system.

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Bulletins & Catalogs

PACKS. Electronic Measurements Co., Inc. Bulletin 765 B, 8 pp. Reviews basic features and advantages of the Regatron series of continuously variable dc power supplies. Five typical applications are described and illustrated.

(321) ADJUSTABLE-SPEED DRIVES. Cutler-Hammer, Inc. Publication EN-65, 14 pp. Covers the Ultraflex M line of packaged drives for 1-to-200-hp application. Shows how a three-phase, full-wave magnetic amplifier provides an adjustable dc voltage to the motor armature for precise control.

(322) SIZE 8 SERVOMOTOR. Helipot Corp. Data Sheet 1370, 4 pp. Offers systems engineers a complete description of the Beckman 400 cps, Model 8-SM-460 servomotor, first of its kind to be built for operation at 115 volts. Illustrations include dimension drawings as well as torque-speed and power-speed curves.

(323) INSTRUMENT SIMPLIFICATION. The M. W. Kellogg Co. The Kelloggram, 1958 Series, Issue No. 2, 12 pp. Entitled "The Application of Innovation in Engineering Systems", this new brochure outlines a creative approach to process plant instrumentation systems. Uses typical refinery processes, a light-ends tower, and a vacuum tower to illustrate a technique for instrument simplification.

(324) 60-FINGER REGULATOR. Electric Regulator Corp. Bulletin No. 604, 6 pp. Details the operation and application of the Size 4 Regohm, a new 60-finger regulator for direct control of voltage on the main fields of large alternators and generators, line load regulation, power amplification, impedance matching, and system stabilization.

(325) DIGITAL SYSTEM SIMULATOR. Aeronutronic Systems, Inc. Bulletin, 4 pp. Shows how a new digital systems simulator serves as a powerful tool in the synthesis of digital computers, data processing equipment, and other digital equipment. A typical design problem is used to illustrate operation.

(326) STRAIN-GAGE RECORDING. B & F Instruments, Inc. Bulletin 451 BCD-12-58, 4 pp. Summarizes design and construction features of a new line of multichannel strain-gage recording and plotting systems. Detailed specifications cover a 24-channel control and scanning module that serves as the basic building block for the systems described.

(327) MEASURING AND LOGGING. The Vapor Recovery Systems Co. Bulletin CP-3704, 4 pp. Announces the new pulse code data gathering and reduction system, which can accommodate almost any kind of logging program and will handle such variables of liquid storage and transportation as liquid level, temperature, pressure, and positive displacement meter readings. Smallest-capacity unit takes 48 points; logging rate is 10 points per min.

(328) SUBMINIATURE SERVO. Servo Development Corp. Bulletin, 4 pp. Covers Model 20-200 Servo, which can be assembled as a pre-engineered 1½-in. mechanism fitting into a standard 2-in. case. Uses can be as an aircraft instrument, panel indicator, control mechanism, actuator, computer element, etc.

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ABSTRACTS

High-Speed Random Access

From "Fundamental Concepts in the Design of the Flying Spot Store" by C. W. Hoover Jr., R. E. Stachler, and R. W. Ketchledge, all of the Bell Telephone Laboratories. Paper presented in the Bell System Technical Journal, Vol. XXXVII, No. 5, September 1958, pp. 1161-1194.

The flying spot store described here is a photographic storage system developed for use with an experimental electronic telephone switching system. It provides a high-capacity semipermanent memory arranged for rapid random access to stored words.

Information is stored as a pattern of transparent and opaque spots on a developed photographic emulsion. In a multichannel unit, reading is accomplished by light beams from a cathode-ray tube. These beams pass through an array of objective lenses operated in parallel. Each lens images the working area of the CRT on a separate film plane. A photomultiplier detector behind each film plane senses the light only when the spot being addressed is transparent. Placing one bit of each word at the same address on each of the film planes permits parallel readout with a single beam positioning. Usually the number of channels is made equal to the desired word length.

Fig. 1

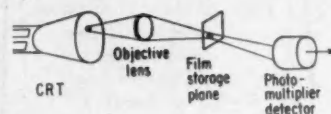


Figure 1 illustrates the operation of a single channel.

One very important consideration in developing a flying spot scanner type of access is analog accuracy in beam positioning. Studies show that to maintain discrimination and capacity, the beam should be positioned within 0.1 spot diameter. To provide this accuracy for a 500 by 500 spot array on the CRT would require regulation within 0.02 percent of both the accelerating voltage supply and the deflection amplifier power supply. Thus, in the multichannel unit developed at Bell Labs, beam position is controlled by a specially developed closed-loop feedback system. Several of the parallel optical channels contain code plates. Bar patterns on these plates are designed so that readout from the chan-

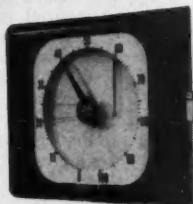
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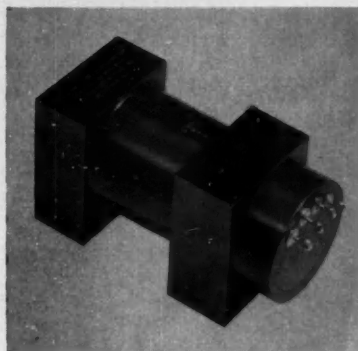


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156 CONTROL ENGINEERING

ABSTRACTS

nels gives the cartesian coordinates of the beam position at all times in parallel binary form. A parallel digital comparator provides an error signal by comparing this position readout with the required address position. The error signal is applied to integrating and deflection amplifiers in tandem to drive the beam to within one-spot diameter of the correct position. Linear servo action then locks the beam to the single code-plate edge passing through the cell at the address selected. Figure 2 shows a schematic of

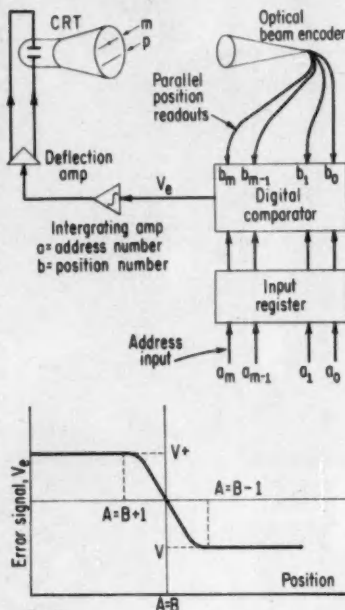


Fig. 2

this system and a plot of the error signal as a function of position.

Another important consideration in developing a system of this type is the discrimination ratio, defined as:

$$\frac{S_{1, \min} - S_{0, \max}}{S_{0, \max}}$$

where $S_{1, \min}$ is the minimum amplitude of a 1 signal read out from the store and $S_{0, \max}$, the maximum amplitude of a 0 signal. For the laboratory model described in this paper a minimum ratio of 10:1 was established. Main factors contributing to the degradation of this ratio are the shot noise component of photocathode current and the regenerative noise component of anode current. Tests of a new photomultiplier tube indicate that regenerative effect can be reduced, making shot noise the limiting factor.

Producing the desired photocathode current requires a certain flux level;



EECO

Minisig SENSITIVE INDICATORS

...with built-in high-sensitivity transistorized driver circuits to operate directly from low-level signals, where signal excursion is too small for direct operation of neon or incandescent lamps. Most Minisigs have adjustable operating characteristics controlled by bias voltage.

WIDE SELECTION

New Minisigs now include filament-type, high-temperature-type, memory-type, and plug-in-type units, as well as miniature and subminiature designs. Here are some typical additions to the growing Minisig family:

FILAMENT TYPE

Model R-441 is a high-gain indicator employing a low-voltage plug-in incandescent lamp. Gives bright light when input level is -11.0 volts.

HIGH-TEMPERATURE TYPES

Models R-561 and R-661 incorporate silicon transistor circuits for operation in the temperature range -55°C to $+100^{\circ}\text{C}$.

MEMORY TYPE

Model R-901 employs a Raytheon CK-1050 lamp. Anode current of 3.0 ma yields much brighter light than an NE-2 glow lamp at max. rating.

PLUG-IN TYPE

Model R-1004 assembly includes outer shell and R-1005 encapsulated plug-in insert for easy servicing. Provides basic flexibility of application of R-101 and R-201. Extends $1\frac{1}{4}$ " behind panel; mounts in $\frac{1}{2}$ " hole.

MINIATURIZED DESIGNS

Models R-121 and R-221 require only $1\frac{1}{4} \times \frac{1}{2}$ " diam. over-all behind panel and mount in $\frac{3}{16}$ " hole.

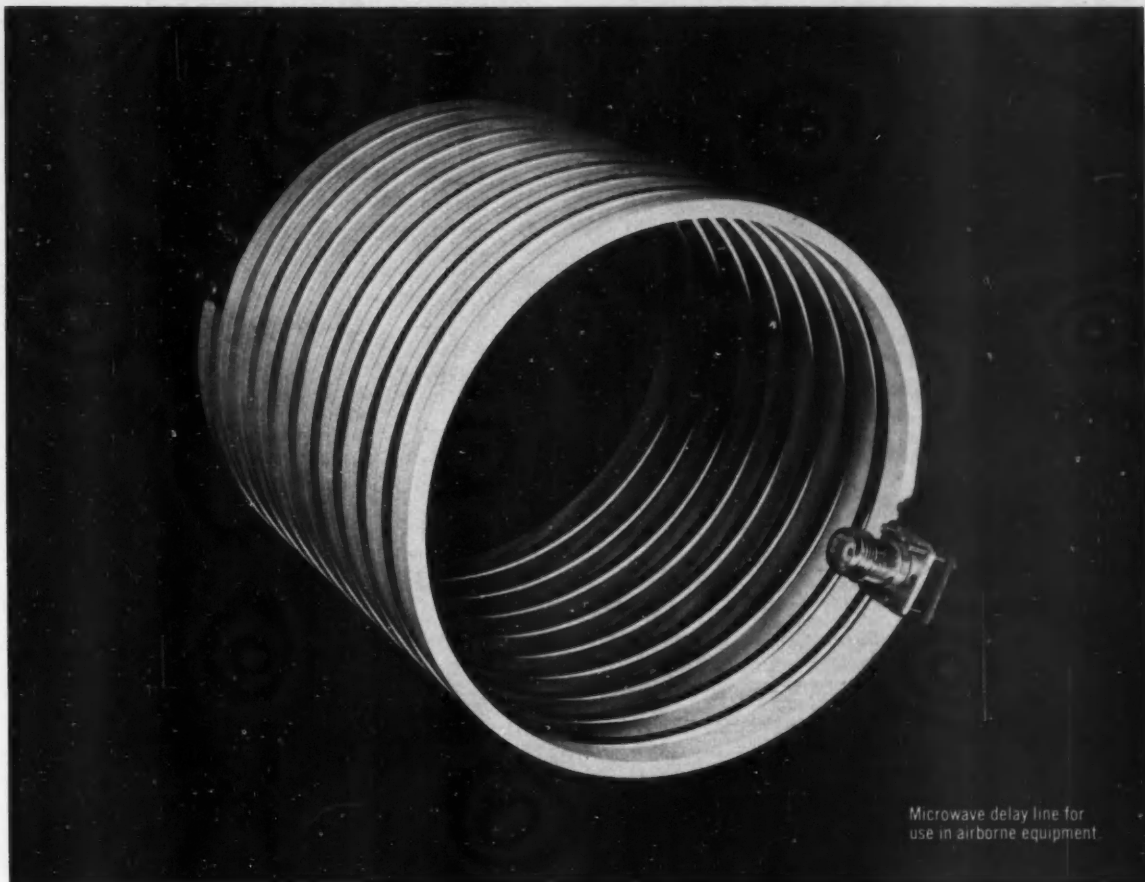
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Microwave delay line for use in airborne equipment

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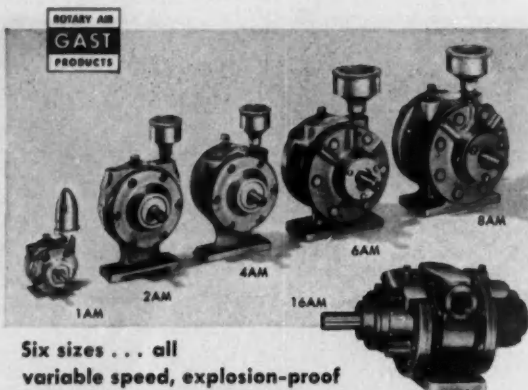
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4AM	1.1	8
6AM	2.0	17
8AM	4.0	25
16AM	7.0	65

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ABSTRACTS

this means establishing flux levels throughout the system and imposing limits on the choice of photomultipliers, cathode ray tube, and optics. In addition, flux density at the focal point must be made high enough to provide proper exposure of a new film plane, since the same system is used for both reading and writing.

Characteristics of the experimental model include a 35,721-bit capacity and word lengths of 18 or 36 bits requiring assembly from two or four readouts. Film planes in each of nine parallel storage channels provide 64 by 64 arrays on 1.5-in.-square areas. Each 10-stage photomultiplier tube operates with an output current of 350 ma and a total gain of about 200,000. A sampling amplifier connected to the photomultiplier output provides further gain to make detection less dependent on power supply voltages.

On Using PD Meters

From "Application of Positive Displacement Metering in the Pipeline Industry" by Paul A. Mankin, Rockwell Mfg. Co. ISA Paper No. PTW-7-58, presented at the 13th Annual Instrumentation-Automation Conference & Exhibit, Philadelphia, Pa., September 1958.

The pipeline industry continually finds new applications for positive displacement meters. Work horses of the industry, they perform the very important task of measuring flow of a wide variety of petroleum and chemical products with excellent repeatability and accuracy.

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One of the more interesting applications and one which requires considerable thought, is the metering of highly volatile liquids such as lp gas, butane, propane, etc. Biggest problem here is vaporization of the product due to pump starvation, temperature changes, flow restrictions, and mechanical agitation.

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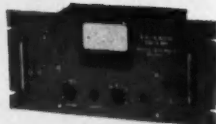
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 TEST TIME..... 2-120 seconds
 NUMBER OF TEST TERMINALS..... 11

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NEW BOOKS

Before SAMA and Now

THE SCIENTIFIC INSTRUMENT INDUSTRY, James R. Irving, director of public information, Scientific Apparatus Makers Association, 60 pp. Published by Bellman Publishing Co., Cambridge, Mass. \$1.

James R. Irving belongs to that rare species of person who is in love with his work, knows a great deal about it, and writes about it in an engaging way. His two most important interests, chemistry and public relations, meet in this booklet, No. 98 in Bellman's series of vocational and professional monographs, to provide an exciting and educational experience for the reader who wants to know something about the history and applications of scientific instruments, and the opportunities the industry they represent offers to the career-seeker.

The years between the discoveries of the first measurement techniques and the application of modern instrument technology are rich in names such as Newton, Faraday, Hooke, Laplace, and others. Irving covers these years, and the men who influenced them, by means of an entertaining mixture of history, biography, anecdote, and descriptions of some of the actual scientific experiments performed. This is followed by a section on United States developments alone.

In a section on the "tools" of science, Irving divides the scientific instrument industry into six basic areas: industrial instruments, laboratory apparatus laboratory equipment, nautical, aeronautical, and military instruments, optical products, and recorder-controllers. Following a brief description of each, he lists names and addresses of the best-known manufacturers.

This list, and a few words about some of the companies in it that were early leaders in the instrument field, serve as an introduction to a history of SAMA itself. Once that is given, Irving turns to areas of use for instruments and to opportunities for work in the field. His discussion of these opportunities, and of the aptitudes and personal desires without which they can never be any more than opportunities, is a stimulating and inspiring contribution to the book.

Reformations in education now being tried out or adopted by secondary schools, such as the Pittsburgh plan for Pittsburgh's Allegheny High School, complete the major part of the text. Irving appends a selected list of professional, trade, and government organizations, and a bibliography.

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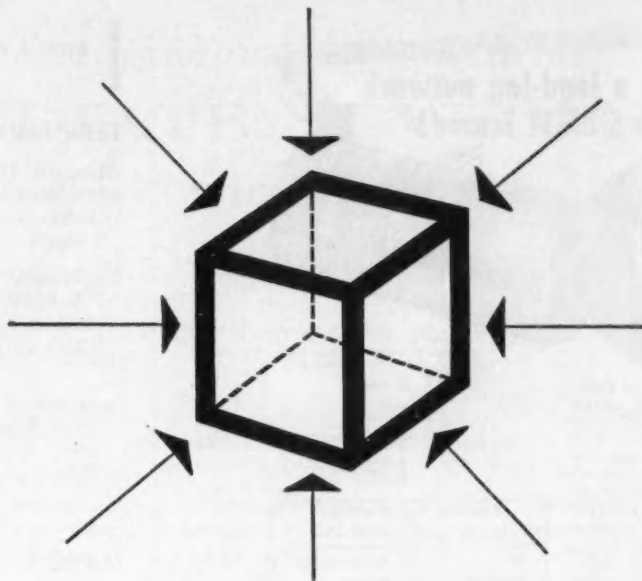
Minimum requirements are actual experience plus B.S. and advanced degrees in E.E. and Physics.

For more information please write to: Mr. K. B. Stevenson, Engineering Personnel, North American Aviation, Inc., Los Angeles 45, California.

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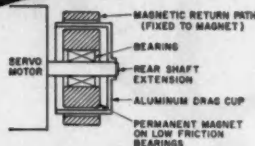


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WHAT'S AHEAD: MEETINGS

FEBRUARY

Materials Handling Exposition and Conference, Automotive Building, Exhibition Park, Toronto, Ontario, Canada Feb. 2-6

Engineering Institute (short course), "Automatic Control for Process Industries", University of Wisconsin Extension Division, Madison, Wisc. Feb. 11-12

Institute of Radio Engineers, The 1959 Solid State Circuits Conference, University of Pennsylvania, Philadelphia Feb. 12-13

MARCH

Western Joint Computer Conference. Theme: New Horizons with Computer Technology, Fairmont Hotel, San Francisco March 3-5

American Institute of Chemical Engineers, National Meeting, Session on Computing Control (March 17th), Chalfonte-Haddon Hall Hotel, Atlantic City, N. J. March 16-18

Institute of Radio Engineers, 1959 National Convention and Exposition, Waldorf-Astoria Hotel and New York Coliseum, New York March 23-26

American Society of Mechanical Engineers, IRD Conference, sponsored by AIEE, IRE, ISA, and AICHE, Case Institute, Cleveland March 29-April 2

21st American Power Conference, sponsored by Illinois Tech, Hotel Sherman, Chicago, Ill. March 31-April 2

APRIL

International Atomic Exposition and Nuclear Congress, Public Auditorium, Cleveland April 5-10

Instrument Society of America, Second National Symposium on Chemical and Petroleum Instrumentation, St. Louis, Mo. April 6-7

American Institute of Mining and Metallurgical Engineers, 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Ovens and Raw Materials Conference, Jefferson Hotel, St. Louis, Missouri April 6-8

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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient fileable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

Fundamentals of Tie-Motor Control, 12 pp. Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of tie motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, how to interpret a plot in terms of system performance, and how to synthesize nonlinear

Continued on Page 166

Reprint Order Form

Reprint	Unit price	No ordered	Subtotal
Fundamentals of Tie-Motor Control.....	\$0.30
How to Use Phase Plane Techniques.....	\$0.40
Economics in Control.....	\$0.50
Electronic Process Control Systems.....	\$0.40
Report on Russian Control.....	\$0.40
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CONTROL ENGINEERING

REPRINTS cont'd

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What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability.

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Soviet Countdown:

How The Russians Put Lunik into Orbit

Here are the first technical details on guidance, control and tracking systems used by Soviet space scientists. McGraw-Hill's Bonn World News Bureau put this unusual and exclusive story together by interviewing reliable intelligence sources in Germany. We've rushed it into print because of its interest and importance to CtE readers.

BONN, GERMANY—The first man-made planet, launched by the Soviets on Jan. 2, 1959, at 10 a.m. GMT, was powered by a three-stage, 104.9 ft vehicle, instrumented to impact Lunik against the moon. Documented reports from the U.S.S.R., including projected flight paths, make it clear that the Soviets intended to strike the moon roughly at a point along its equator, not pass it at a distance of 2,187 miles, as the Soviets finally disclosed they had done.

In the simple guidance system (see diagram right) a perforated strip programmed coarse control while a directional radio beam provided a fine control that permitted the Russians to come within 3 deg of their target. The Soviets were able to cut off third-stage burning with 0.1-sec accuracy when Lunik achieved an escape velocity of 6.98 miles per sec.

Russian space scientists blame strong magnetic fields prior to third-stage cutoff for their failure to hit the moon. However, the near-miss indicated that all systems functioned within tolerable limits.

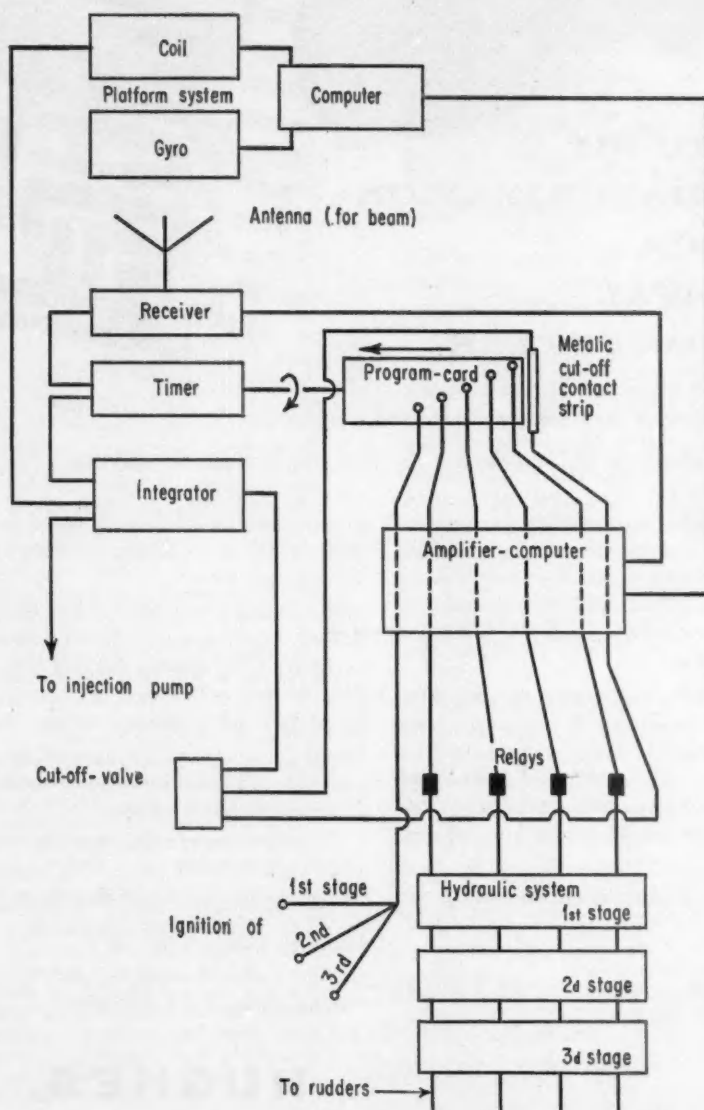
Designated CH-10, the launching vehicle weighed 352,000 lb, had an initial thrust of 660,000 lb, and was similar to the units which launched all three Sputniks. Launching took place at a point on Latitude 47 deg North, and Longitude 62 deg 30 sec, slightly to the northeast of the Aral Sea on the border of European Russia. Lunik first headed south, then turned in an easterly direction. Actual angle of injection was 71 deg from the vertical.

For the moon shoot, all nonessential equipment was stripped from the Russian space vehicle. There was not even any provision for destruction in flight. However, instrumentation was retained for measuring magnetic fields, cosmic radiation, radioactivity, interplanetary matter, micrometeorites, corpuscular radiation, and temperatures. Four radio transmitters relayed the information to earth. A

fifth unit was installed as a standby transmitter.

Lunik boasted at least two major design innovations. For the first time, all electronic equipment in the rocket was fully transistorized. And two-dimensional printed circuits were incorporated.

• **Power plant**—The launching vehicle consisted of a first stage, which was a modified T-3A ICBM; a second



Block diagram of coarse and fine guidance control

stage, a modified T-2 IRBM; and a third stage, specially designed for space flight. Lunik's first stage was supplemented by two solid-fueled Golem 3 rockets (surface-to-air missiles). Previous Sputniks did not use this extra lift.

Initial thrust of the first stage was divided so that 484,000 lb came from the first stage unit, 88,000 lb from each of the Golem rockets. The two solid-fueled boosters were jettisoned at 6,600 ft. The first-stage liquid-fueled engine burned out 80 sec after launch. Like the other two stages, it used a mixture of hydrocarbon and boron additive with liquid oxygen in a ratio of 2.4:1. Second-stage ignition was initiated by first-stage burnout. However, separation was delayed until the second-stage engine was operating at full thrust. Speed of vehicle after first-stage burnout: 1.00 mile per sec.

Burning time of the second stage was 55 sec, its thrust 410,000 lb. The engine, weighing 113,300 lb, including 94,600 lb of fuel, had been modified to handle the specially-designed fuel. Normally, the T-2 engine burns a mixture of alcohol and liquid oxygen. Speed after second-stage burnout: 3.36 miles per sec.

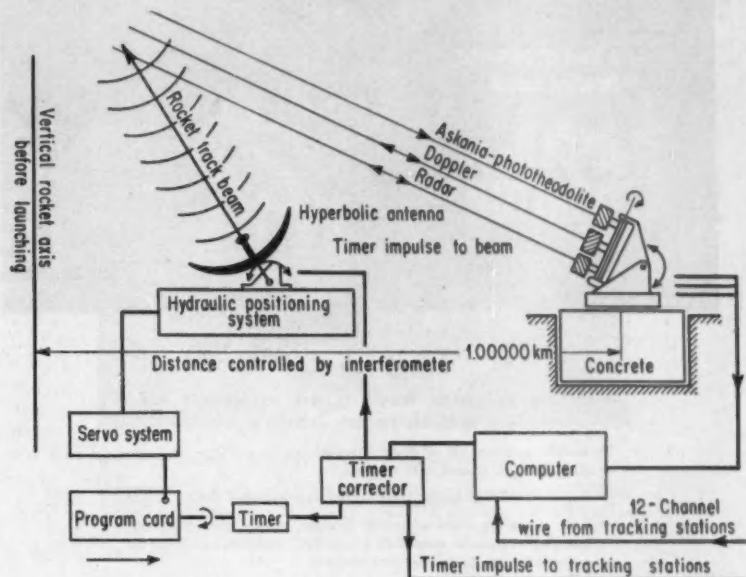
The third-stage engine provided a thrust of 99,000 lb. It burned for 50 sec, at the end of which the vehicle velocity was 6.98 miles per sec, sufficient for it to escape from the earth's gravitational field.

Thrusts in the second and third stage provided sufficient reserve power to spin the vehicle to 60 rpm, using graphite guidance rudders to provide stability. (Current U.S. practice: spin moon probes with vernier rockets.)

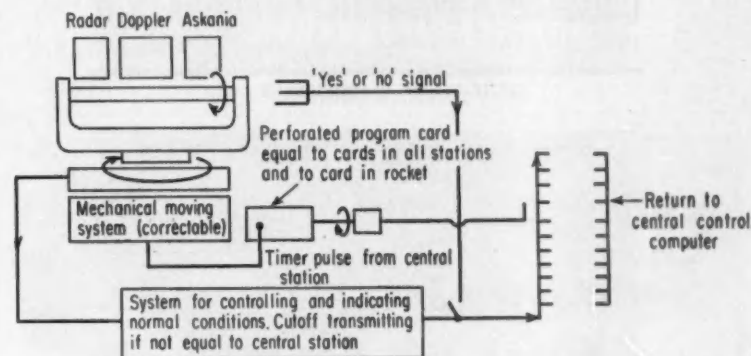
• **Guidance and control**—Guidance equipment was physically located in the third stage of Lunik and on the ground in the main control center, a precisely measured 1.00000 kilometer (3,280.84 ft) from the pad. A two-word description of the system is "time-guided".

The ideal flight path was programmed on an aluminum-perforated card, which was driven by an electronic quartz timer, both housed in the rocket. On the ground, for fine control, a perforated iridium card, similar to the one inside the missile and carrying identical commands, programmed movements of a hyperbolic antenna, which supplied a beam for the Lunik to ride. An electronic timer in the rocket was pulse-synchronized with an identical timer on the ground.

For fine guidance, the beam was provided by a 5,000-watt hyperbolic antenna, quartz-controlled on a 12-cm wavelength. Direction signals to the



Block diagram of central control station.



Block diagram of tracking station.

hydraulic-actuated antenna were sent from a digital computer, similar to the IBM 704. Variations in ambient temperature, wind, pressure, and humidity were manually corrected in a worm gear computer. Temperature changes that might have distorted the antenna reflector were measured by thermocouples; this data was relayed to a computer which made the necessary correction via hydraulic cylinders to maintain correct focus of the antenna.

Three liquid-damped gyroscopes in each of Lunik's three stages acted on a stabilizing platform to control roll, pitch, and yaw. Gravitational influences on the vehicle were compensated by the gyro system; magnetic influences tending to cause the missile to roll or pitch were corrected by two

induction coils. A third induction coil, coupled directly to an integrator, kept a close control on vehicle acceleration by governing the pressure of fuel injected into the thrust chamber.

The efficiency of the Soviet guiding system, say experts, can be traced to this combination of gyroscopes and induction coils. It kept all three axes of the vehicle at correct tangents to the preset path, while beam control kept its center of gravity on the prescribed path.

Guiding pulses generated by gyroscopes or induction coils were transmitted via an airborne computer to an amplifier and to a second computer coupled to the perforated-card program control. Through relays, the pulses were transformed to hydro-

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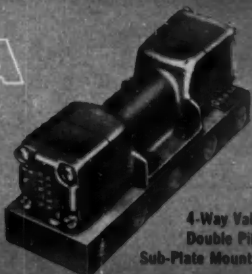
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CONTROL ENGINEERING

Soviet Lunik . . .

mechanical movements which altered the position of the four graphite rudders located at the end of the rocket nozzle.

Correcting impulses sent up by the ground-to-missile beam were picked up by a receiver and transmitted via the timer to an integrator unit. After integration, the correcting pulses were relayed to the amplifier/computer and then over the hydromechanical system to the vehicle rudders. As on previous Sputnik vehicles, the Russians preferred graphite rudders acting on the thrust stream to the heavier and more cumbersome gimbal-hunt engine used by U.S. spacemen.

• **Instrumentation**—A globular instrument chamber in the nose cone of the third stage contained essentially the same instrumentation as employed in the last Sputnik.

► **Magnetometer** instrument had a dual purpose; to measure the strength of the magnetic fields, and to measure the intensity and intensity variation of the cosmic rays through which the planet passed.

► A single twin-chamber Geiger-Mueller counter was used to register the photons in cosmic rays at the same time as the second chamber was determining radioactivity of the moon. Both chambers together determined the distribution of heavy nuclei caused by cosmic radiation.

► A nitrium spectral analyzer was designed to determine and measure the components of interplanetary matter.

► A micrometeorite erosion gage measured corpuscular radiation and micrometeorite particles.

► Skin temperature and the temperature in the instrument chamber were registered and measured by conventional thermocouples. It is now known that the temperature in the instrument chamber varied between 59 and 68 deg F.

To reduce weight in planet payload, Soviets pared down instrument weight to allow the inclusion of five transmitters, each with a 6-watt input and an average output of 1 watt. Four transmission frequencies enabled information obtained during flight to be transmitted back to earth. The four announced frequencies were 19.993 mc, 19.995 mc, 19.998 mc, and 183.6 mc.

It is believed that the Russians assigned each transmitter one frequency. Inter coupling was arranged so that in event of a transmitter failure, its frequency would be shifted to another transmitter. The fifth transmitter was held in reserve and, in emergency, could transmit information on all four of the selected frequencies.

Information picked up by the planet's instruments was to be simultaneously forwarded to earth by all transmitters.

Transmitters started operating 10 min before zero time and were intercoupled with a magnetic trip system so that, should transmitter failure occur prior to burnout of the last vehicle stage, the fuel system would be cut off and vehicle would leave its path. Reason for this was an apparent unwillingness by Soviets to have Lunik traveling through space silently.

• **Tracking**—Tracking is accomplished by 13 sets of doppler, radar, and phototheodolite units. One set is located at the central control, the other 12 at tracking stations connected by land lines to the control center. Data from all units is collected and fed into a digital computer. All the trackers are fixed, about its vertical and horizontal axes, to a common tubular mounting rotatable, and the entire system is supported on a concrete base poured into the earth.

Doppler is conventional, utilizing a parabolic reflector. Radar operates on a 12-cm wavelength, employs a screen approximately 9.8 ft in diameter. Theodolite uses an Askania system.

• **The countdown**—Russians claim the launching took place "on time".

As the time came near for the actual firing, here's what happened: 60 minutes prior to firing, electronic equipment in the main control station and in the 12 subsidiary tracking stations was switched on and checked.

At the launching pad, 60 min before firing, all rocket instruments were checked. At 10 sec prior to firing, nitrogen-driven gyroscopes in the rocket were started up.

At 5 sec to launch, 1) gyros had to be at full speed, 2) first stage turbine had to be at full speed, 3) rocket had to be delivering full liquid engine thrust of 484,000 lb. If one of these three conditions was not fulfilled, an automatic check would have prevented firing button from actuating at time zero.

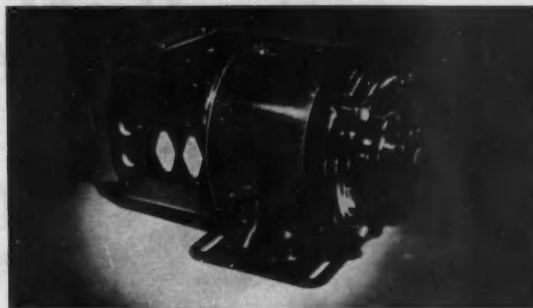
Between minus 10 sec and minus 5 sec, the mission could have been aborted by manually blocking, if any one in bunker detected a defect via instrument panels or visually. At minus 5 sec, with tanks full, all-up weight was sent to the computer at main control station. External fuel-feed was cut out and simultaneously feed from first stage tanks cut in, all automatically.

At time zero, with conditions normal, the fire button ignited solid-fueled Golems and threw off retaining anchors, launching the vehicle.

—Morrie Helitzer
Jim Morrison



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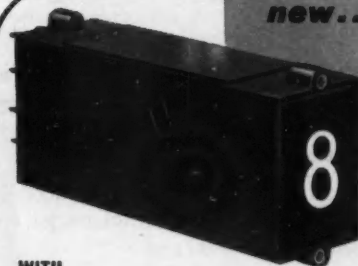
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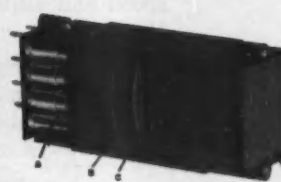
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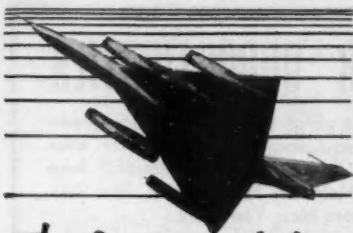
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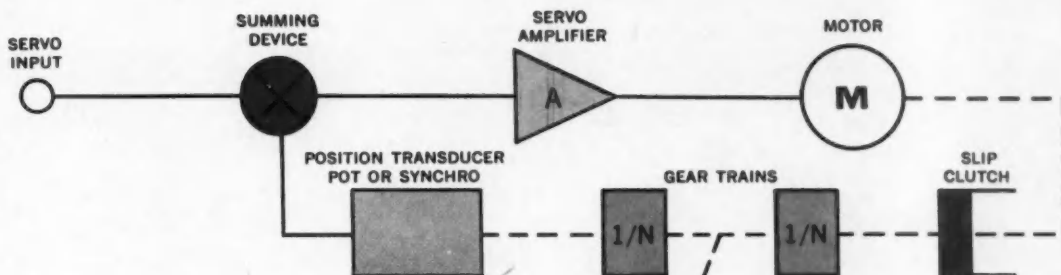
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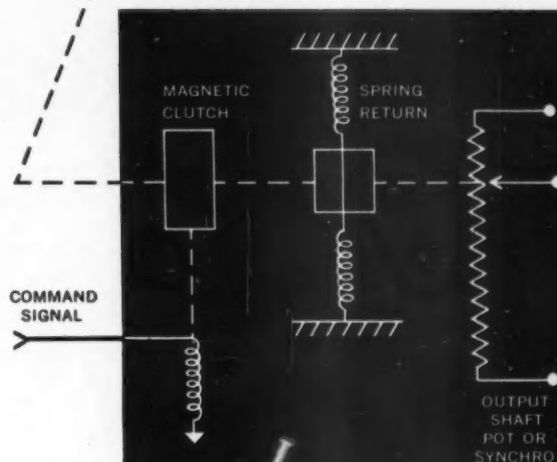
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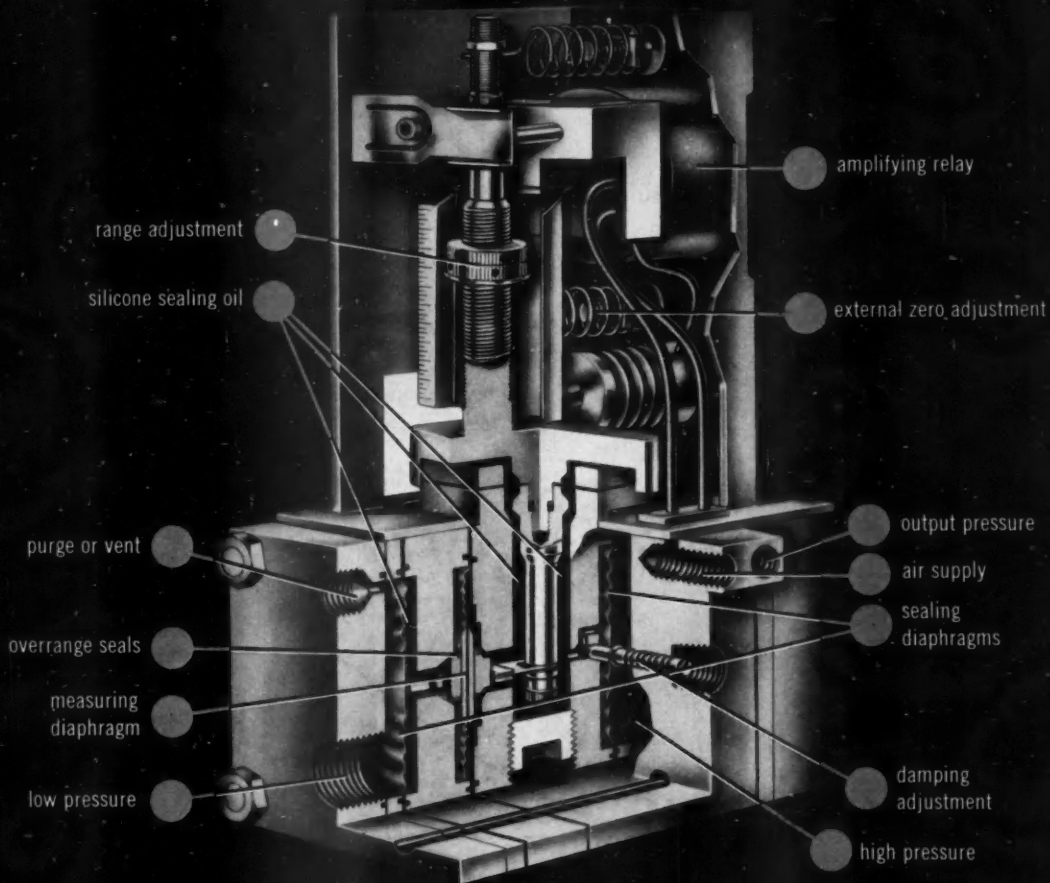
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